Proceedings of the 9th ICAZ Conference, Durham 2002

Colonisation, Migration and Marginal Areas

A zooarchaeological approach

Edited by Mariana Mondini, Sebastián Munoz and Stephen Wickler

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Proceedings of the 9th Conference of the International Council of Archaeozoology, Durham, August 2002

Series Editors: Keith Dobney, Peter Rowley-Conwy and Umberto Albarella

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Preface

Umberto Albarella, Keith Dobney and Peter Rowley-Conwy

This book is one of several volumes which form the published proceedings of the 9th meeting of the International Council of Archaeozoology (ICAZ), which was held in Durham (UK) 23rd–28th August 2002. ICAZ was founded in the early '70s and has ever since acted as the main international organisation for the study of animal remains from archaeological sites. The main international conferences are held every four years, and the Durham meeting – the largest ever – follows those in Hungary, the Netherlands, Poland, England (London), France, USA, Germany and Canada. The next meeting will be held in Mexico in 2006. The Durham conference – which was attended by about 500 delegates from 46 countries – was organised in 23 thematic sessions, which attracted, in addition to zooarchaeologists, scholars from related disciplines such as palaeoanthropology, archaeobotany, bone chemistry, genetics, mainstream archaeology etc.

The publication structure reflects that of the conference, each volume dealing with a different topic, be it methodological, ecological, palaeoeconomic, sociological, historical or anthropological (or a combination of these). This organisation by theme rather than by chronology or region, was chosen for two main reasons. The first is that we wanted to take the opportunity presented by such a large gathering of researchers from across the world to encourage international communication, and we thought that this could more easily be achieved through themes with world-wide relevance. The second is that we thought that, by tackling broad questions, zooarchaeologists would be more inclined to take a holistic approach and integrate their information with other sources of evidence. This also had the potential of attracting other specialists who shared an interest in that particular topic. We believe that our choice turned out to be correct for the conference, and helped substantially towards its success. For the publication there is the added benefit of having a series of volumes that will be of interest far beyond the restricted circle of specialists on faunal remains. Readers from many different backgrounds, ranging from history to zoology, will certainly be interested in many of the fourteen volumes that will be published.

Due to the large number of sessions it would have been impractical to publish each as a separate volume, so some that had a common theme have been combined. Far from losing their main thematic focus, these volumes have the potential to attract a particularly wide and diverse readership. Because of these combinations (and because two other sessions will be published outside this series) it was therefore possible to reduce the original 24 sessions to 14 volumes. Publication of such a series is a remarkable undertaking, and we are very grateful to David Brown and Oxbow Books for agreeing to produce the volumes.

We would also like to take this opportunity to thank the University of Durham and the ICAZ Executive Committee for their support during the preparation of the conference, and all session organisers – now book editors – for all their hard work. Some of the conference administrative costs were covered by a generous grant provided by the British Academy. Further financial help came from the following sources: English Heritage, Rijksdienst voor het Oudheidkundig Bodemonderzoek (ROB), County Durham Development Office, University College Durham, Palaeoecology Research Services, Northern Archaeological Associates, Archaeological Services University of Durham (ASUD), and NYS Corporate Travel. Finally we are extremely grateful for the continued support of the Wellcome Trust and Arts and Humanities Research Board (AHRB) who, through their provision of Research Fellowships for Keith Dobney and Umberto Albarella, enabled us to undertake such a challenge.

Two of the 24 sessions organised included the themes of "Colonisation and Migration" and "Marginal Areas". Since these broad study areas cover much common ground, it was obvious that these sessions should be conjoined for the purposes of publication.

Research into the nature and extent of human dispersal throughout the world has been (and still is) one of the major topics of archaeological research over the last 50 years. Although archaeologists have made much progress in understanding the temporal and geographical extent of large and small-scale human movement and trade and

exchange networks, fundamental questions remain largely unresolved and, as a result, numerous, often contradictory, hypotheses abound.

Much of our current understanding of human dispersal and exchange networks is based upon the distribution of "culturally distinct" objects such as pottery and other artefacts. Scientific techniques such as elemental source characterisation of e.g. stone adzes, basalt and obsidian artefacts, slate and flint, have also been employed not only to demonstrate long-distance voyaging, but also to measure the relative isolation or interaction of human groups. However, in many of these current debates, a potentially important source of information has remained largely unexplored; i.e. the study of animal remains (zooarchaeology). Humans transported not only themselves, but also other organisms by land and sea, both during dispersal events as well as through regular exchange networks. Evidence indicates that a whole spectrum of vertebrate taxa was involved depending on geographic location and time period. Some were moved by accident, others were deliberately transported.

The rapid radiation of peoples around the globe during the Late Pleistocene and subsequent Holocene also brought them into new and often extreme environments, which depending on definitions, could be termed "marginal". Studies of human adaptation to these new and challenging circumstances, and their subsequent impact upon them have perhaps a longer tradition of employing zooarchaeological evidence. However, although many sites key to our understanding of this broad theme, have produced often large assemblages of animal bones, in too few cases have these potentially important datasets been used to address issues beyond simple diet and subsistence.

It has become abundantly clear during the last decade or so that zooarchaeological evidence can be utilised to address issues beyond simply those of calorific intake, and this was splendidly attested by the variety of broad themes included in the ICAZ 2002 conference programme. With more holistic and integrated approaches to data assimilation and analysis, new and more dynamic interpretative frameworks are now being constructed with which to better understand the human past. Zooarchaeology is now beginning to take its rightful place at the table where broader and more significant archaeological questions are now debated and the 13 diverse papers included in this monograph make an important contribution to this progress.

When the themes of the two sessions presented in this volume edited by Mariana Mondini, Sebastian Muñoz and Stephen Wickler were proposed for the ICAZ conference, we enthusiastically agreed as they had the potential of stimulating exactly the type of debate we were hoping for. We were not disappointed, and it is appropriate to see these sessions published as a book, which we are confident will be of great interest for readers of many different backgrounds.

Part I

Human and Animal Migration and Colonisation

9th ICAZ Conference, Durham 2002
Colonisation, Migration, and Marginal Areas (ed. M. Mondini, S. Muñoz & S. Wickler) pp. 2–3

1. Introduction to the Session: *Human and Animal Migration and Colonisation*

Stephen Wickler

The initial part of this volume contains papers from the ICAZ conference session *Human and Animal Migration and Colonisation*. As this was one of the smaller sessions, with a total of seven presentations, it was decided to combine these papers with contributions from the session on *Behavioural Variability in the so-called Marginal Areas* in a single published volume. The session organiser, Prof. Atholl Anderson, was unable to attend the conference so I was subsequently given responsibility for chairing the session and editing the papers submitted for publication in this volume. Taking Anderson's outline for the session as a starting point, I provide a brief introduction to the general theme of migration and colonisation followed by an overview of the papers presented in the session and those appearing in this volume.

As Anderson states in his session outline, interdisciplinary research in archaeology, genetics and historical linguistics has been instrumental in initiating a process whereby models of migration and colonisation are being rehabilitated to explain episodes of extensive cultural change. The renewed interest in prehistoric population movements over the past decade has led to the production of models to explain the process (see Anthony 1997; Chapman and Hamerow 1997; Burmeister 2000). However, the utility of such models is dependent on the reliability of the empirical data upon which they are based and the ability to link archaeological observations to an explanatory framework in which migration is of central importance. As Ashby points out in his contribution to this volume, faunal remains are an important and promising medium for the documentation of human movement in the past but the development of appropriate methods for their use is paramount if their full potential is to be realised. This brings us back to the key importance of interdisciplinary research in providing the most effective use of the tools at our disposal for elucidating evidence for colonisation and migration.

The session was organised with the intention of exploring the potential for perspectives linking human and animal migration and colonisation by drawing on zooarchaeological evidence. This in turn provided an opportunity to define and discuss some of the pertinent issues linking human and animal behaviour in antiquity. Potential topics of interest cover a wide spectrum including the ability to differentiate between migration and other forms of mobility, disentangling migration from other agencies for change such as diffusion and independent invention, the utility of biogeographical models and contrasts between continental versus island colonisation and the patterning of migration episodes in relation to causality, duration, and cessation. The session organiser was particularly interested in encouraging the presentation of well-documented archaeological datasets and case studies related to relevant theoretical issues.

The range of papers presented at the session was extremely diverse with a minimal degree of overlap both in terms of temporal and geographical distribution. The seven presentations included a general paper on the problem of migration and more specific papers addressing zooarchaeological data from North America (2 papers), Oceania (2 papers), Europe, and Greenland with a time span ranging from the European Neolithic to the American Colonial Period. Thematically, a majority of the papers dealt with aspects of agricultural colonisation including historic European settlement in Virginia (Arbuckle), Neolithic population movements in Oceania (Szabo,Wickler) and the Norse colonisation of Greenland (Enghoff). Apart from this aspect, the contributions had no overarching thematic unity although they did touch upon a number of issues discussed above in the process of attempting to link zooarchaeological evidence with appropriate theoretical models.

The four session papers published in this volume are both too few in number and too diverse for any attempt at categorisation. Ashby's contribution presents a timely and concise overview of potential methods for recognising

and extracting information on past human movement from zooarchaeological evidence. He also makes the important point that in order to fully exploit the potential of zooarchaeology, we must allow for the integration of other forms of archaeological, scientific, historical and linguistic evidence. The emphasis on appropriate methodologies and the necessity of a multidisciplinary approach is reiterated in Geigl and Pruvost's paper on the potential of paleogenetics in mapping Neolithic migrations through the study of cattle domestication in Europe.

Arbuckle and Bowen are also interested in documenting physiological changes in cattle, but in this case study the focus is on biometric data from archaeological sites in the Chesapeake region of colonial Virginia from the 17th and 18th centuries. Changes in cattle size caused by nutritional change are convincingly related to shifts in patterns of land use on the part of European colonists. The process of changes in cattle size is modelled in relation to stages in the process of agricultural colonisation which the authors suggest may have parallels with agricultural colonisation elsewhere in the world. Similar faunal characteristics of agricultural colonisation such as a dramatic decline in faunal richness and the frequency of wild taxa are noted by the authors in Polynesia and it is argued that these shared trends are indicative of a similar underlying process.

The final paper by Wickler focuses on the process of agricultural colonisation and migration in Micronesia using zooarchaeological evidence for prehistoric human transport of animals. An examination of introduced fauna from archaeological contexts in Micronesia reveals a disjunct distribution which defies simplistic attempts at tracing population movements based solely on the presence or absence of any given species. The observed patterns reveal the complexity of past human behaviour and cultural selectivity of decisions regarding animal translocation in Oceania.

Despite the limited number of papers presented in the session and subsequently published in this volume, the collective presentations contribute a variety of useful information and insights into the utility of zoological applications in addressing the complex and multifaceted aspects of colonisation and migration in the past. It is encouraging to see that the renewed interest in archaeological models of colonisation and migration as explanatory mechanisms for change is reflected in current zooarchaeological perspectives.

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Colonisation, Migration, and Marginal Areas, (ed. M. Mondini, S. Muñoz & S. Wickler) pp. 4–9

2. Understanding Human Movement and Interaction through the Movement of Animals and Animal Products

Steven P. Ashby

In recent years, the concept of human migration has re-emerged in archaeological discussion. However, to date there has been no explicit review of the role that zooarchaeology may be able to play in this field of debate. A variety of zooarchaeological techniques may be exploited; species biogeography, metric and non-metric variation are all important areas of research.Furthermore, several other techniques may help to elucidate the problem of related human and animal movement, including the recognition and sourcing of animal products, and genetic analysis of modern animal populations and ancient faunal remains. The integration of these fields of study with other methods (including some often considered to be outside of the archaeological canon) is fundamental to the understanding of human movement and interaction, and the current lack of a theoretical framework for the study of such phenomena is a major problem.

Introduction

This paper outlines ongoing work which began as a dissertation written for the University of York's Master of Science course in Zooarchaeology. That piece of work (Ashby 2001) consisted of a critical review of the literature relating to the use of animal remains and products in the recognition of human movement and interaction. In this paper, I will focus on the use of faunal remains in the recognition of human migration.

Renewed archaeological interest in migration in the last decade has fostered considerable research into the process and nature of population movement, and models for its comprehension have been proposed (Anthony 1997; Burmeister 2000). However, before the utility of such models can be tested, a good understanding of the archaeological patterning that may indicate human movement is necessary. The differentiation of migration and exchange is notoriously difficult, and we have yet to develop satisfactory methods for the recognition and study of these phenomena (see Burmeister 2000, 539–541).

If we are to begin to understand and recognise human movement in antiquity, it is paramount that all avenues of research are exploited. Faunal remains are a medium which may be effectively utilised in this manner. In this paper I will discuss the application of a variety of techniques to the study of human migration.

Species Biogeography

Perhaps the clearest indication of animal movement and concomitant interaction of peoples is through the presence of species recorded beyond their known geographic ranges. The remains of such species may be recognised in faunal assemblages, while the raw materials of animal products such as textiles and worked bone may also be identified. By noting chronological changes in species distribution we may track the spread of animals and begin to understand patterns of human interaction. This technique has been famously employed in the study of the spread of domestication (*e.g.* Harris 1996) as well as the movement of domestic animals in later periods (*e.g.* Hoffman 1994). The movement of commensal species (see Armitage 1994), and the importation of wild game animals (see Yalden 1999, 153, 158–160) may also help to reveal patterns of human interaction.

A good example is the case of the black rat, *Rattus rattus* (see Rackham 1979; Armitage *et al.* 1984; O'Connor 1991; Armitage 1993; 1994; Ervynck 2002). Populations of *Rattus rattus* were present in Roman Britain, but seem to have declined with the demise of their urban habitat that preceded the Roman withdrawal (O'Connor 1991). They appear to have been absent from Britain between the 6th and 8th Centuries, but large populations were renewed by the end of the first millen-

nium; a time when long range trade clearly seems to have been more important. Notably, their distribution expanded further in the postmedieval period, when settlement of the Americas began (Armitage 1993). Thus, it seems that the success of *R. rattus* populations closely mirrors changes in human movement and interaction. The distribution of *R. rattus* remains may therefore be a useful proxy for long range exchange and movement.

Work by Elizabeth Reitz (1999) provides a nice contrast with this work. When studying faunal assemblages from first nations sites in colonial Florida, Reitz failed to find evidence for significant uptake of domestic animals by Native Americans. This can be explained in ecological and cultural terms, but it seems possible that the social change that a move to the husbandry of domestic animals required was not justified by the potential gains. Reitz's work shows that in cases where human choice is involved, social identity may sometimes prove too resilient for us to recognise the impact of overseas contact through faunal remains. Thus, studies of the commensal and parasitic fauna (particularly small mammal remains) become extremely important.

However, we need not always look for the movement of animals to recognise human migration. Local extirpations, such as that of Cyprus's pygmy hippopotamus (*Phanourios minutus*) may be linked with the arrival of humans (Simmons 1988; MacPhee and Burney 1991). Conversely, animals dependent on the environment created by man may become extinct when humans desert a region (see Brothwell and Jones 1978).

Animal products may also prove to be of use if we can recognise and source the species from which the material of a craft object comes. This has been attempted on antler material at Birka (Ambrosiani 1981) and Novgorod (Smirnova 1997, 139, 145). Similarly, the physical nature of textile fibres may be of use in determining the location of manufacture. When distinctive fibres are discovered beyond their known biogeographical ranges, such as the finds of bison hair in medieval Greenland (Walton Rogers 1998), they may be seen as imports or introductions. Although the movement of such products may often be related to trade rather than explicitly to migration, it may act as supporting evidence if other indications of population movement are observed.

Unfortunately, there are a number of problems with these biogeographical approaches. In addition to considering the possibility of natural animal migration, it is important that we assess the likely effects of temporal change in topography, climate, or habitat, rather than simply assuming a human role in the introduction or extirpation of a species (see MacGregor 1985, 40–41; Vigne 1999, 310). Furthermore, we cannot assume that the absence of a given species in the record indicates a real absence in the past. The true absence of an animal from a region may only be confirmed through meticulous sieved recovery (see O'Connor 1991). We should also be wary of postulating the introduction of species on the basis of a small number of osteological finds, given the fact that archaeological assemblages rarely give an accurate indication of ancient wild fauna. Notwithstanding these problems, the approach shows promise and, when identification based on morphology is possible, has the advantage of being relatively inexpensive.

Metric Variation

It may also be possible to apply biogeographical techniques to variation below the species level, though it should be pointed out that we are not searching for evidence of breeds in the modern sense, but merely regionally distinct genetic types. One way of proceeding is through the analysis of metric variation. The measurement of bones and teeth is important in the inference of animal movement on a range of scales, but it is fundamental that we first account for the effects of all biological variables. Age and sex may be controlled to some extent by the exclusion from study of strongly sexually polymorphic elements and bones with unfused epiphyses (*e.g.* Maltby 1979, 35; see Reitz and Wing 1999, 170). Unfortunately, environmental factors are more difficult to control for, and it is well known that nutrition may affect growth, particularly during the first years of development (see, for example McMeekan 1940).

In an attempt to control for environmental variables, many analysts have used dental measurements as a marker for genetic difference, under the assumption that tooth growth is relatively environmentally independent (see Payne and Bull 1988; Albarella *et al.* 1997). However, this belief has not been satisfactorily proven, and it is conceivable that malnutrition or serious infection prior to calcification may affect tooth growth (see Mays 1998, 78). There is some experimental evidence for retarded tooth development as a result of stress *in utero* and during the period of tooth formation (*e.g.* Paynter and Grainger 1956; Tonge and McCance 1965). Thus, while it may eventually be shown to be a valid assumption, the environmental independence of tooth size should not be accepted without evidence from controlled experiments. However, ethics limit dietary variation, and mean that today's experiments are more often based on dietary improvement than depletion (*e.g.* Kim *et al.* 2001).

An alternative is to look at bone shape variation, which may be expressed as the difference in relative measurements (see Albarella 2002). While this may be largely unaffected by nutritional factors (although see Bridges 1989), other variables such as sex, age and pathology must be considered (see Albarella *et al.* 1997; Jurmain 1999).

Taking these factors into account, Murphy *et al.* (2000) noted that Roman Age cattle metapodials from Great Holts Farm, Essex were considerably larger, though only a little more robust, than those found at other Roman sites in the

area, and suggested that they represent imported livestock. Thus, when we can account for the various confounds, the study of bone shape variation seems promising, and may lead to interesting insights (see Albarella 2002), but much more research is required if we are to ascertain the reliability and usefulness of this approach.

Non-Metric Variation

Animal populations, and thus their movement, may also be recognised through the occurrence of non-metric traits. Unfortunately, this subject has suffered from a general lack of research until recent years and many zooarchaeological references to them have been little more than reportage (see O'Connor 2000, 119). However, certain traits have been subject to a little more study, and the field seems to be growing. Here is not the place to go into their details explicitly, but a brief summary is appropriate.

Once again, teeth are of particular interest, as their characteristics may have potential as indicators of genotype (see O'Connor 2000, 120–21). The absence of the second mandibular premolar in bovids has frequently been commented on, but is not yet well understood. The development of the lower third molar may also be useful, as the distal hypoconulid is sometimes underdeveloped or absent.

Also in cattle, the genetic or environmental origins of perforations in the neurocranium have caused debate (Brothwell *et al.* 1996; Manaseryan *et al.* 1999), while the shape of the sagittal profile has also been commented upon (Grigson 1976), although apparently not commonly studied in recent years. In sheep, the position of the femoral nutrient foramen may also be useful, perhaps as an indicator of restricted gene flow or isolation (Noddle 1978, 138; O'Connor 2000, 121–122).

Another potentially informative bovid trait is the presence or absence of horns. Mark Maltby (1994) studied assemblages from Winchester, and noted that early Roman deposits contained a mixture of horned and polled sheep, while assemblages from the hinterland were clearly dominated by the horned variety. This disparity is supported by metrical data, and it seems possible that most of the sheep at Winchester were of a polled variety and were generally larger in size than those from the excavated rural assemblages. It thus seems that the town was provisioned by at least two sources.

Clearly then, there are a number of avenues for research into non-metric variation. Moreover, this field of study may have advantages over metrical analysis (Sjøvold 1973, 212). Firstly, work may still be possible if the material is heavily fragmented or deformed. Secondly, it is possible that the occurrence of many non-metric traits is largely sex-independent. If this can be substantiated, then it will allow the recording of traits from skeletal fragments for which sex cannot be determined.

It is also possible that non-metric traits are less subject to environmental variables than metric traits (see Sjøvold 1973, 206; Berry 1979, 670). However, neither seems to be under such strict genetic control that it is unaffected by other factors. Indeed, experiments on mice found that development of the third molar was affected by maternal nutrition (Searle 1954). Thus, on the whole, the environmental independence of non-metric traits is unconfirmed, and further research into this area is needed. If such an independence can be established for certain traits, then they may prove to be of considerable utility in the recognition of animal populations. However, a greater understanding of their origins, together with more systematic recording are needed if we are to exploit these phenomena to the full.

DNA Analysis

While future advances may help us to unravel the complex relationship between genotype and phenotype briefly discussed above, a solution now seems less pressing, as the advent of DNA analysis has enabled us to use new techniques in the understanding of culture contact.

Although as yet under-exploited, there is potential for the study of genetic variation in present day animal populations to tell us about human movement. This is particularly true of animals that are closely associated with man and the environment that he creates. Work by Matisoo-Smith and colleagues on Pacific pigs and rats (*Rattus exulans*), and Susan Haynes's study of the origins of the distribution of the Continental (or Orkney) vole *Microtus arvalis* are of particular note (Matisoo-Smith and Allen 1997; 2001; Haynes 2000).

However, work on modern populations is problematic. When attempting to source the migrants to a region, be they animal or human, we must accept that recent migrations and genetic drift may have taken place, and may have had a significant effect on the gene pool (see Mays 1998, 203). The study of ancient DNA thus becomes paramount, as it allows us to add a temporal perspective to the data obtained from the genetic study of present day populations.

Interesting work has already been accomplished in this relatively young field. There is a considerable body of work on the introduction of the rabbit (*Oryctolagus cuniculus*) to the Mediterranean, as deduced from aDNA analysis (Hardy *et al.* 1994a; 1994b; 1995), while Allen *et al.* (2001) are currently attempting to clarify the genetic history of pigs in the Pacific region. By detecting the transfer of suid stock, it is possible to gain some understanding of human population contact in the Pacific, and the introduction of new breeds into Polynesia following western contact clearly affected native pig populations (Allen *et al.* 2001, 4–5). A DNA analysis may thus soon begin to improve our knowledge of Pacific migration and trade (Allen *et al.* 2001, 9,12).

However, it should be remembered that the success

rate of ancient DNA analysis is generally very low. In addition to precluding the analysis of small assemblages, this may hamper attempts to answer questions regarding temporal or spatial variation in large assemblages, and may make the generation of generalising hypotheses impossible (see Haynes 2000, 164). Moreover, until the cost of DNA analysis decreases, such investigations will often be unavailable to many projects (Barnes 1998, 80).

Furthermore, DNA extraction necessarily damages bone. At present we have little understanding of preservation processes (Hagelberg *et al.* 1991), and cannot readily recognise samples that are likely to yield 'good' DNA, or decide on the best method of extraction, although Susan Haynes and others seem to have recently made some inroads into this field (Haynes *et al.* 2002). Moreover, contamination is a serious concern, and extreme measures must be applied to minimise the risk of its occurrence (see Brown and Brown 1992, 20; Haynes 2000, 29).

All in all the potential of genetic techniques in this field is clear, but there are still some problems to be resolved. We are not yet in a position to say whether these techniques are likely to supercede traditional approaches, and it is clear that we must work towards a better understanding of both morphological and DNA-based analysis.

Discussion

How do any of these techniques further our knowledge of human migration? One of the most important questions we can ask is how we differentiate the phenomena of exchange and population movement. To generalise, the deliberate and widespread introduction of foreign species or genotypes may suggest some level of population movement, while more isolated occurrences may be interpreted as the products of trade or individual travel. In order for this distinction to be made, a thorough knowledge of the excavated and historically recorded fauna for the area and time period of interest is fundamental.

In the case of taxa that may not have been deliberately imported, the scale of the introduction may not be helpful. The reproductive rate of rats, for example, together with the size, fragility and concomitant sampling issues of small mammal bone make it difficult to use numbers as criteria for the inference of migration rather than trade (see Elton 1958; Armitage 1994). Thus, while commensal animal finds may clearly suggest overseas contact, they must be used as part of a system together with domestic animal remains, artefacts and other forms of evidence if we are to differentiate between exchange and population movement. Some progress may be made if context and ethology are carefully considered. For example, we may ask if the animal in question was likely to have been transported with traded commodities, such as furs or grain, or whether its first appearance coincided with human migrations known from other sources of evidence.

Thus, the most sensible approach seems to be one of integration, with context considered as a major component of interpretation. The zooarchaeological and biological methods discussed in this paper should be combined wherever possible, through the collaboration of multiple analysts. Each line of evidence should be studied individually, and subjected to a series of validity checks, before being compared and combined with other forms of evidence (*e.g.* Harlan and de Wet 1973). Furthermore, evidence garnered from these studies should be explicitly considered alongside material from other areas of archaeological and non-archaeological study, so that the archaeological, physical and chemical studies of animal, botanical and human remains may be integrated with the study of buildings and artefacts, and documentary, epigraphic or linguistic evidence. These multifarious analytical techniques will not always support each other, but neither should they be expected to. The comparison of the findings of various approaches can only lead to a better understanding of the processes of human movement and contact (see Morales Muniz 1997; Albarella 1999).

Above all, it is vital that we apply these techniques within a clear theoretical framework. A better understanding of the process of migration is necessary if we are to be able to reliably differentiate between processes of movement and contact. It is important that we take into consideration the models of migration devised by social anthropologists and geographers (see for example Ravenstein 1885; Zelinsky 1971; Massey *et al.* 1993), and use these to construct our own framework for the understanding of migration. Such a theoretical underpinning will help to improve our recognition of the signs of population movement that appear in the archaeological record. Thus it is hoped that an integrated strategy for the understanding of culture contact may be constructed.

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3. Plea for a Multidisciplinary Approach to the Study of Neolithic Migrations: the Analysis of Biological Witnesses and the Input of Palaeogenetics

Eva-Maria Geigl and Mélanie Pruvost

The Neolithic revolution is characterised by the invention of agriculture leading to population expansion and migrations of human and animal populations and is key to understanding the present success of the human species. The complexity of the Neolithisation process has begun to be revealed by recent evidence collected by various scientific disciplines. Different scenarios have been proposed: (i) autochthonous cultural evolution, or cultural change by (ii) physical colonisation or (iii) assimilation of ideas and know-how. In our eyes, understanding the bases of human culture requires a thoroughly integrated and concerted interdisciplinary approach. In particular, we emphasise the importance of the contribution that can be brought by the analyses of biomolecules of human and animal origins and the richness of the palaeogenetic approach. Even though these analyses of biomolecules are destructive, we plead for a thoughtful but large-scale study of animal bones. As modern investigative methods are technically elaborate and sensitive to multiple artefacts, reliable results can only be obtained through close collaboration of experts in the various disciplines.

Introduction

Environmental changes might have been the driving force pushing Mesolithic hunter-gatherers to search for new food sources. This may have provided a catalyst for the invention of agriculture, which had a strong impact on humans at both the individual and communal level. On one hand, the labour of agriculture impoverished the health of the individuals, as revealed by skeletal modifications. On the other hand, it ensured reliable nutrition for the community, which translated into demographic expansion. This demographic pressure pushed early food-producing farmers to migrate into scarcely-populated geographical regions in Eurasia where they more or less gradually outcompeted or, to a probably lesser degree, mixed with local hunter-gatherers thereby spreading their genes, resistance to crowd disease, and their culture including language, domesticated plants and animals, etc.

This scenario, reviewed by J. Diamond (2002), has summarised recent archaeological and genetic evidence of the early events leading to the Neolithisation of Europe. There is general agreement that it is the invention of agriculture and domestication of animals and plants in different regions of the world that led to the so-called Neolithic revolution about 10,000 years ago. It swept over the entire planet and brought about deep changes in the organisation of human societies, which paved the way for modern times. In order to shed light on this complex, multi-facetted process results from more 'classical' approaches such as archaeology, palaeoanthropology, archaeozoology, palaeobotany and palaeopathology must be integrated with the 'modern' molecular approaches such as population genetics, palaeogenetics and isotopic studies. We will present the different approaches, their advantages and drawbacks and some of their major results in the study of Neolithic domestication and migration phenomena.

Studying the phenomenon of cattle domestication in Europe, in this article we show how our first results from palaeogenetic analyses of bovine fossils align with the present day theories and hypotheses of Neolithisation. We will take the opportunity to present a personal view of what we consider to be the main hypotheses at present and against these we will compare our results. This will be done from an interdisciplinary perspective and thus none of the fields contributing to this research will be

covered exhaustively. It will define the framework of our project and explain the value of a multidisciplinary approach. Using the genetic information preserved in fossil cattle and aurochs bones of various geographical and temporal origin, we try to retrace the migrations of domesticated cattle from the Near East into Europe as well as some of the possible mixing events with local wild bovine populations. Since these animals and man coevolved, this will also give us clues to human migrations and population demography.

Molecular Studies of Ancient Biological Material: the Contributions and Limits of the Palaeogenetic Approach to Phylogeography

The analysis of DNA preserved in fossilised remains has the potential to improve the study of past populations as it could minimise the drawbacks inherent in the reconstruction of phylogenies using genetic analyses of present day sequences. The classical approach relies on DNA sequence divergence to infer phylogenetic trees. It relies on the basic assumption that DNA sequences evolve at a constant rate, the so-called molecular clock hypothesis. However, it is clear that this assumption is often invalid as there is evidence that changes in the environment favour bursts of genetic changes (Giraud *et al.* 2001). Thus, differences in selection pressures over time, including human interventions and population bottlenecks, change the rate of DNA sequence evolution. If the rate of DNA sequence evolution is not constant, the sizes of the branches of the phylogenetic trees and thus the overall morphology are not correct. This could in part explain the numerous discrepancies between the reconstruction of the evolution of a given species based on genetic sequences and on morphological features.

The palaeogenetic approach allowing DNA sequence and morphology to be correlated in the same fossil remains should help to reestablish the proper time scale at various nodes of the phylogenetic trees and to reconcile the molecular analyses of the modern specimen and the morphological analyses of the ancient specimen. Moreover, data resulting from a palaeogenetic approach are independent of the age of the animal at the time of its death, they are likewise independent of morphological intra- and interpopulational polymorphisms, sexual dimorphisms, the preservation of the morphological information content of a particular skeletal element, and the morphology-influencing taphonomic preservation of the fossil (such as fragmentation, partial burning, deformations due to compaction, etc.).

These advantages render the palaeogenetic approach highly attractive for the analysis of ancient population migrations of animals and humans and, in combination with the genetic analysis of modern animal populations, have led to impressive insights into the domestication processes of various animals such as cattle (Troy *et al.* 2000), horses (Vilà *et al.* 2001, Jansen *et al.* 2002), dogs (Leonard *et al.* 2002), and rabbits (Hardy *et al.* 1995) that could not have been obtained using purely conventional approaches. These studies achieved a considerable phylogeographical resolution in both time and space demonstrating the power of palaeogenetics.

However, the palaeogenetic approach is limited both technically (for a review see Hofreiter *et al.* 2001) and in absolute terms, as the number of fossil samples, in which the genetic information is chemically preserved, is probably low. In fact, work on ancient DNA is hampered by specific difficulties caused by the severe chemical damages that DNA is subject to during the fossilisation process leading to chemical modifications of the information content and to a substantial loss in material. As a consequence, contamination of fossils and fossil extracts by modern DNA constitute one of the major problems of ancient DNA work and require specific and rigorous precautions.

Moreover, statements on ancient population migrations require detailed pictures of ancient population variations, and thus analysis of large samples that are not always easy to obtain. Furthermore, since DNA sequences have different evolutionary histories, phylogenies derived from a single genetic loci are unreliable as observed upon comparison of phylogenies based on both a nuclear and a mitochondrial sequence (Shaw 2002). Although Neolithic and modern populations share a great deal of their history 'written down' in their genome, data from the analysis of mitochondrial sequences, if used alone, do not provide the resolution necessary for a fine-tuned phylogeographic study. Therefore, analyses of various genetic loci of the nuclear genome, like microsatellites and single-nucleotide polymorphisms, are necessary. Last but not least, all palaeogenetic analyses have to be repeated multiple times to identify contamination of the samples and fossil extracts with modern DNA (Cooper and Poinar 2000). For this reason, each fossil has to be analysed several times in one laboratory, verified against other samples from the same context and then the experiments repeated in another laboratory. This procedure requires more than just a few milligrams of the fossil material, which is limited in number and mass.

Human Neolithic Migrations I: Integrating Archaeology and Population Genetics

Three mutually exclusive scenarios for the Neolithisation of Europe can be imagined: (i) independent development of agriculture by Mesolithic cultures without contact with populations from Anatolia and the Fertile Crescent (Jeunesse 1987; Lüning 1989; Gronenborn 1999; Schweizer 2000); (ii) the cultural diffusion model, i.e. a purely cultural transmission of ideas and practices of agriculture without a significant population movement

from Anatolia and the Near East being at the origin of the Neolithisation of Europe (Dennell 1983; Bellwood 2001), which implies a continuous presence of interrelated peoples in Southeast Europe throughout the Palaeolithic-Neolithic continuum (King and Underhill 2001); (iii) a massive movement of people conveying their culture and implying a significant genetic input of Near Eastern genes from Neolithic farmers. This latter scenario is proposed by the demic diffusion model, developed from large genetic data sets (Ammermann and Cavalli-Sforza 1984).

Scenario (i) has been hypothesised from findings that have been interpreted as a newly emergenging pottery tradition known as 'La Hoguette' thought to be derived from local Mesolithic peoples who had begun to practise horticulture and herding several hundreds of years before the arrival of the Neolithic immigrants (Jeunesse 1987; Lüning *et al.* 1989; Gronenborn 1999; Schweizer 2000). However, these cases seem to be rare. Although geographically and ethnically distinct, the local Mesolithic foragers/horticulturalists and the farming immigrants seem really to have coexisted for quite a while (Gronenborn 1990; Lüning *et al.* 1989). They were already in contact via trading networks during the 8th millennium BC before the decline of these Mesolithic cultures during the 7th millennium (Price *et al.* 2001). The two other scenarios for the diffusion of farming and associated technologies into Europe described above are based on archaeological, genetic and linguistic evidence and have been controversially discussed until recently.

There is no doubt that the Neolithic farmers caused the spread of the 'agricultural complex' (Lüning 2000), *i.e.* domesticated plants and animals, a process that made the Neolithic transition a global phenomenon (for a summary see Diamond 2002). This happened mostly along east-west axes, where similar conditions were found. The rapidity of the spread to new territories that were scarcely populated demonstrates a high mobility on the part of the Neolithic immigrants (Lüning 1988, 2000). Evidence for this diffusion pattern comes mostly from archaeological results and remains to be correlated with the results of the sciences dealing with biological material.

Briefly, archaeological evidence (like incised ceramic vessels, polished stone axes, village dwelling) points to population movements via two main migration routes out of the Near East (for a recent and comprehensive summary see for example Lüning 2000). The first diffusion through sea routes along the Mediterranean coasts proceeded to the Iberian Peninsula and to Southern France. From there it moved towards the North to meet with the second diffusion moving over the Balkans and spreading out gradually over Central Europe and into Western Europe (for a review see Lüning 2000). These migration routes have been confirmed by new, comprehensive radiocarbon dating approaches (Lenneis *et al.* 1996; Zilhao 2001).

These results should be confronted with the results from population genetic studies of paternally (Y chromosome) or maternally (mitochondrial DNA) transmitted haplotypes (arrangements of specific alleles or DNA sequence character states on a single chromosome). Specifically, the particular distinctive clinal patterns of mitochondrial or Y chromosomal haplotypes over space mark trajectories of gene flow and, by inference, the origins and movements of populations (King and Underhill 2001). Recent investigations of the non-recombining region of the human Y chromosome support the evidence that large movements of people accompanied the introduction of farming to Europe (Richards *et al.* 2000; Rosser *et al.* 2000; Chikhi *et al.* 2002). This result does not exclude that, in some regions and to a lesser degree, local admixture scenarios occurred concomitantly (Chikhi *et al.* 2002). In fact, from the South-East to the North-West of Europe, a gradient from 25% to near-0% of individuals with Near Eastern haplotypes has been found (Richards *et al.* 2000; Semino *et al.* 2000).

However, it should not be neglected that present-day patterns of genetic variation in populations could have been generated by many different demographic, mutational and/or selective processes (Goldstein and Chikhi 2002). As these authors state, extrapolations to ancient populations from the data raised from the investigation of modern populations are inferential in nature. They are subject to considerable uncertainty stemming from the inherent variability of the evolutionary process and a variety of other complications such as modelling assumptions (Goldstein and Chikhi 2002). Therefore their interpretation requires information stemming directly from ancient material. The first steps in the direction of an approach combining archaeological evidence with that stemming from ancient and modern human biological material have been undertaken (*e.g.* King and Underhill 2001; Bellwood 2001; Brown and Pluciennik 2001; Götherström *et al.* 2002), so far, however, mainly to investigate geographical regions outside of Europe (Horai *et al.* 1991; Gibbons 1994; William 1995; Merriwether *et al.* 1994; Hagelberg 1997).

Human Migrations II: Isotope Studies of Human Migrations

Very recently, another molecular approach to the problem of human migrations became available, *i.e.* strontium analysis of human skeletal remains. Strontium isotopes provide a geochemical signature of the place of birth and the place of death (Price *et al.* 2001). In particular, differences in the strontium isotope ratio between the bone and the tooth enamel of the same individual indicate a change in residence during life as strontium from the food chain is incorporated in the hydroxyapatite mineral of skeletal tissue where it is stored (Price *et al.* 2001). The differences in strontium content between the teeth, reflecting the *in utero* or youth nutrition of the individual,

and the bones, remodelled throughout a lifetime and therefore reflecting the nutrition throughout the individual's life, has the potential to reveal aspects of immigration patterns (Price *et al.* 2001 and citations therein). There are also limits to this approach as only first generation migrants can be identified (Price *et al.* 2001). Moreover, post-burial contaminations of archaeological bone during diagenesis by strontium in the ground water complicate the analysis. However, a non-local isotopic signature is always considered as significant as contamination is a local signal thereby avoiding the identification of locals as immigrants (Price *et al.* 2001). This approach produced first results pointing to a high importance of migration in the spread of the *Linearband Keramik* (LBK) (Price *et al.* 2001). The assignment of the isotope signal to the analysed skeleton, the sex of which has been determined by palaeoanthropological methods, allows inferences to be drawn about the social structure of these early Neolithic societies, about intermarriage across agriculture/foraging frontier zones (Price *et al.* 2001), which have to be confirmed by independent approaches due to their ambiguous nature if considered alone.

The Spread of Animal and in Particular Cattle Domestication into Europe: What Archaeology and Archaeozoology tell Us

The study of extant populations and remains of domesticated animals is a complement to the study of the Neolithisation processes via the analysis of traces of the Neolithic cultures and the genetics of modern human populations. To do so, it is crucial to examine the sequence, temporal placement and social and environmental context of domestication (Zeder and Hesse 2000).

The definition of domestication comprises a whole range of gradual differences. At one end of the spectrum, domestication of animals can be viewed as a form of behavioural co-evolution that was beneficial to both of the species involved or at least one of them and neutral to the other (O'Connor 1997). This implies that humans have also been domesticated by agriculture, the consequences of which can be seen on the medical, the genetic, the morphologic and the behavioural level, as domestication is not a one-way event (Diamond 2002). At the other end of the spectrum, there is the anthropogenic definition of domestication as the collective mastering and control of an animal population by a human society for a service or use as primary material (*e.g.* Helmer 1992; Vigne 2000). A definition of domestication laying between these two extremes views it as a gradual fluid process continuing a long time before the selective breeding, the evidence of which are complex shifts in population levels, pasture quality, technology and social conditions. This definition implies that societies shifted between symbiotic pastoralism and pure hunting before they finally began herd management (Ingold 1974; Marean 2000).

Although the habitat of the wild ancestor of present day cattle covered Europe and Asia, most archaeozoologists ascribe the first domestication events to the Near East leading to cattle populations that were exported shortly afterwards to reach Europe, Asia and Africa (*e.g.* Uerpmann 1990; Arbogast 1994; Hachem 1995; Tresset 1997; Vigne and Helmer 1999; Lüning 2000, to mention just a few). The diffusion of domesticated cattle concomitantly with the migrating Neolithic farmers from the primary centre in Anatolia into the Eastern Mediterranean area is described as fast and direct. In contrast, the diffusion into the Western Mediterranean area is seen as a complex process of interactions between migrating Neolithic and local Mesolithic population groups that can be characterised as a 'saltatorial diffusion' mode (Vigne 2000). The diffusion in Southern France and Spain seems to have arisen in separate hotspots via 'colonial implantation' (Vigne 2000). Several scenarios for the interaction of the local Mesolithic with the approaching Neolithic can be designed on the basis of archaeological and archaeozoological evidence, including a transmission of Mesolithic traditions to the Neolithic (Pucher and Engl 1997; Lüning 2000).

While it is clear that culture and technology including farming spread in large parts through population migrations, it is unclear whether, in addition, secondary Neolithisation and particularly domestication centres have arisen (as postulated, *e.g.* Pucher and Engl 1997). Questions of date and location of domestication have been addressed using conventional archaeozoological approaches (*e.g.* Pucher and Engl 1997; Lüning 2000; Vigne 2000) as over time, due to the modified conditions of life in captivity, morphological modifications (mainly reduced size and modified shape of certain bones) of the animal bones can be identified and interpreted by archaeozoologists (*e.g.* Helmer 1992; Vigne 2000). However, it remains difficult to distinguish between man-induced changes and those resulting from other biological and environmental factors, except in cases where it is possible to find on the bones direct evidence for secondary usage of animals like traction (Lüning 2000). Indeed, body size is sensitive to many ecological factors and therefore is not an accurate marker of domestication (O'Connor 1997; Zeder and Hesse 2000). Moreover, it is difficult to establish a causal connection between body size reduction and human control and to determine its pace (Zeder and Hesse 2000). Other morphological markers, in particular sexually selected traits, will appear only after numerous generations in the population of domesticated animals and are therefore imprecise indicators of the onset of a domestication process. Alternatively, changes in the age and sex distribution of a faunal assemblage can be analysed via a demographic profiling approach. As age and sex profiles are supposed to reflect the composition of the herd, they would provide an early indicator for

domestication, *e.g.* for controlled breeding and selective harvesting of young males (Zeder and Hesse 2000). However, so far it has proved difficult to construct separate male and female age profiles in order to detect sex-specific harvest patterns of managed herds. Thus, unambiguous distinction between deliberate herd management on one side and selective hunting techniques on the other is far from having been achieved, limiting the value of the approach (Zeder and Hesse 2000). A more reliable documentation of early herd management prior to anatomical changes is possible when the age at death and the culling pattern in the faunal assemblages are examined (Zeder and Hesse 2000).

The percentage of wild animals in the faunal assemblages allows an inference of the importance and nature of the role that hunting, providing an additional nutritional source, played in these societies. It shows the dependence on ecological, economical and social factors (Benecke 1994a, 1994b) as well as on the social status of individual families within a village and in villages of different size (Hachem 1995, 1997).

Using the archaeozoological approach evidence for multiple secondary domestication events has been reported for the Eastern European branch of the Neolithic culture (Pucher and Engl 1997; Lüning 2000 and citations therein). The occurrence of secondary domestication events seem likely in the light of two situations. Firstly, some of the large Eurasian mammals, like the aurochs, having escaped the Late-Pleistocene extinctions, were present on a wide geographic range leaving ample time for independent domestication at other locations than the primary centres in the Near East where the wild counterparts of the domesticates were native (Diamond 2002). Secondly, the exchange of genetic material between the wild ancestors and the domesticated animals would have allowed for the elimination of the negative effects of inbreeding within the herds of domesticated animals. This was the interpretation proposed for Middle Europe by Bökönyi (1984, 1989) of the observed change in the faunal composition of the domesticated herds in favour of cattle and to the detriment of goat and sheep. Domesticated cattle are supposed to have been interfecund with the European aurochs, offering the possibility for the wild animals to contribute to the gene pool of the domesticates. In contrast, the wild ancestors of goat and sheep were not present in Middle Europe. However, the frequency and consequences of these presumed post-domestication events of cattle are hard to assess, especially as they would tend to abolish the tractable behaviour that is the desirable outcome of the selection process by man. Moreover, the reasons for the extinction of their wild ancestor, the aurochs, are unknown, too.

However profound the morphological changes due to the selection by farmers have been, they did in most cases not lead to speciation. For example, the different 'races' of dogs, despite observed differences, are interfecund even with the extant descendants of their ancestors, the wolves. In this case, the existence of the presumed ancestor allows genetic studies to retrace the domestication story (*e.g.* Savolainen *et al.* 2002; Leonard *et al.* 2002). This is impossible in the case of cattle, as their ancestor, the aurochs, became extinct some 400 years ago. The study of the domestication process of cattle is therefore confined to the genetic analysis of modern cattle breeds and to the archaeozoological analysis of fossil remains of aurochs and cattle. The value of the analysis relies on the non-ambiguous distinction between aurochs and cattle, which is difficult because of the pronounced sexual dimorphism of the aurochs. It is even almost impossible for the early stages of domestication when the cattle body size reduction has not yet occurred (Vigne 2000; Uerpmann 2001). This means that only the biggest bones of male aurochs can be attributed unambiguously to *Bos primigenius primigenius* (Pucher 1998; Uerpmann 2001). Moreover, the competition between morphological changes as a result of man-directed domestication and exploitation processes and those due to non-human factors can be hard to distinguish (Hüster-Plogmann and Schibler 1997).

The quantitative and qualitative composition of a Neolithic faunal assemblage contains information about geography, climate, zoogeographical and biological conditions for domestication, aims of utilisation, breeding modes, ethnical and religious traditions and social factors (Bökönyi 1974). All the conclusions drawn from the archaeozoological analyses are based on the number of animal bones found and identified on archaeological sites, on their weight and on the minimal number of identifiable individuals that cannot be inferred without a detailed and thorough taphonomic study of each assemblage. Moreover, archaeozoological analyses are based on measurements and quantitative methods. Statistical methods also need to be applied to these studies of faunal assemblages (Lüning 2000). Furthermore, for these archaeozoological analyses to be valid they never should rely on a single morphological variable. Finally, to get enough pieces for the domestication jigsaw to reflect reality, it is necessary not only to use all archaeozoological parameters available, but also to enrich the existing body of archaeological evidence with genetic data from living and fossil individuals from the largest sample size possible and to confront the resulting hypotheses with each other.

Animal and Particularly Cattle Domestication: Genetic Analyses of Modern Breeds

No clear, generally accepted definition exists for the phenomenon of domestication (Helmer 1992). Here we see it as a gradual multi-step process, the first step of which being the taming or management of individual wild animals by hunter societies for food, bones, skins and fibres (Diamond 2002; Vigne 2000). Later on, these

practices have been applied to groups of animals, which have been isolated from their wild populations to become substitutes for the formerly hunted wild ancestors (Vigne 2000). Domestication as reproductive isolation leading to inbreeding, founder effect and artificial selection leaves genetic signatures: animals have been selected for certain traits that could possibly be retraced by genetic analysis. Moreover, all domesticated populations are characterised by a reduced genetic diversity.

The existence of small populations in the initial state of the domestication may have been responsible for a genetic drift that will cause the disappearance of certain genetic traits still present in the wild population. Thus, these may be used as markers to retrace genetically the origins and diffusion of these populations into other geographical areas during the Neolithic. For instance, genetic analysis can distinguish between the evolution and migration of female and male lineages of a given species by analysing different genetic markers. The investigation of the rapidly evolving maternally inherited mitochondrial DNA provides a powerful tool to analyse the location of the domestication processes as it allows the distinction of maternal lineages within domestic populations that are maintained over very long times even after domestic inbreeding. In fact, although mitochondrial DNA does not reflect the evolutionary history of the whole genome, its analysis has the advantage that it is not troubled by the often transient input of the genomes of wild males on the genetic material of domesticated females (MacHugh and Bradley 2001). On the other hand, mitochondrial DNA data mask the role that male-driven evolution plays. Pre- and post-domestic patterns of sequence diversity, revealing genetic isolation and migrations, can be resolved because the accumulation of substitutions in mitochondrial sequences of some hundreds of base pairs seem to be of a similar time scale than the time depth of domestication (MacHugh and Bradley 2001). This is true if the molecular clock, on which these calculations are based, is correctly calibrated.

The study of mitochondrial DNA of various domesticated animals such as cattle, sheep, pig, and water buffalo confirms the archaeological results mentioned before of a preferential migration route of Neolithic farmers along East-West axes: the sequences cluster into two groups that show a geographical East-West division and are accompanied by a corresponding morphological division (MacHugh and Bradley 2001). The resulting star-like distributions of the two clusters, which show up in unrooted Neighbour-Joining phylogenies of each of these clades and coincides with their East-West geographical distribution, are a strong argument for at least two domestication centres (MacHugh and Bradley 2001). In each of these cases, despite the difficulties of the calibration of the molecular clock, the mitochondrial DNA data point to a most recent common ancestor of all these species more than 100,000 years ago, *i.e.* greatly predating the domestication history of each species (MacHugh and Bradley 2001). The low diversity observed within each clade of cattle, sheep, pig and water buffalo agrees with the suggested capture of a limited number of wild animals followed by their demographic expansion (MacHugh and Bradley 2001). Further studies with larger and more comprehensive samples might reveal additional local and so far hidden domestication events. For example, by extending the study of cattle to African populations a third centre of domestication has been postulated for Egypt (Bradley *et al.* 1996; Hanotte *et al.* 2002), for which archaeological evidence, although present (Grigson 1991), is not generally accepted. Similarly, when a large sampling of the genetically diverse and geographically dispersed modern goat populations has been analysed at the mitochondrial DNA level, more than two domestication centres have been revealed. In addition, these data argue for secondary and tertiary expansions following the initial domestication events and for a high mobility of the species, maybe as these animal formed small and mobile elements of human trade throughout history (Luikhart *et al.* 2001). In contrast, nowadays horses seem to be the product of a domestication process that was less constrained within time and space as real domestication centres did not appear in the mitochondrial DNA analysis of modern and fossil horses (Vilà *et al.* 2001).

Genetic analysis changed the previous and generally accepted hypothesis based on archaeological evidence of a single centre of cattle domestication in the Near East (*e.g.* Epstein and Mason 1984). The study of mitochondrial DNA sequences from modern cattle breeds reveals a clear phylogenetic division between Indian and Afro-European haplotypes. This finding demonstrates that the ancestors of zebu and taurine cattle diverged some hundreds of thousands of years ago and must therefore be the result of at least two biologically independent domestication events (Loftus *et al.* 1994a, 1994b; Bradley *et al.* 1996). This hypothesis is based on a divergence time estimate of 210,000 years for the two subspecies, well before their domestication (Loftus *et al.* 1994a). For this estimate to be valid, mutation rates in the mitochondrial D-loop of human and cattle need to be the same, as the estimated human mutation rate has been used to calibrate the cattle data, and the palaeontologically determined separation of *Bison* and *Bos Leptobos* to be correct (Loftus *et al.* 1996). Network analysis of the mitochondrial DNA sequence data from modern cattle populations identified four haplogroup-clusters. The predominating European haplogroup is also present at high frequency in the Near East together with three other major haplogroups, whereas African diversity is almost exclusively composed of a separate haplogroup (Troy *et al.* 2001). This result provides strong support for a derived Near-Eastern origin for European cattle. The higher genetic diversity among British cattle compared to the European continent showing a greater time-depth cannot be explained for the moment.

These analyses have initiated an interesting approach to the study of Neolithic history. However, they need to be extended to other informative genomic markers, particularly on the Y chromosome, to reveal the evolution and phylogeography of paternal lineages (Edwards *et al.* 2000). The Y-chromosome approach also allowed the analysis of the introgression of male zebus in African cattle populations (Hanotte 2000, 2002). Moreover, genetic diversity should be studied using the rapidly evolving nuclear microsatellite sequences that are present in both sexes and consequently have the potential to reveal the contribution of wild populations to the domestic herds and recent population movements and admixture between divergent populations (MacHugh *et al.* 1997; Loftus *et al.* 1999; MacHugh and Bradley 2001; Shaw 2002). First steps in this direction have already been undertaken. Data from nuclear microsatellite markers, for example, point to the European cattle *Bos taurus* descending from the aurochs *Bos primigenius primigenius* domesticated in Anatolia, and to the Indian zebus *Bos indicus* descending from a Neolithic population of the aurochs *Bos primigenius namadicus* in Pakistan (Loftus *et al.* 1999). They therefore corroborate the hypothesis of a separation of the European and the Indian branch of the auroch during the Pleistocene pushing the separation event even further away, specifically between 610,000 and 850,000 years (MacHugh *et al.* 1997).

However, genetic study of modern bovine populations reveals countless crossings since they have been controlled by man and a recent modification of the distribution of genotypes due to breeding programmes during the last 150 years. This interbreeding complicates the interpretation of the genetic studies of modern populations. Only a palaeogenetic approach allowing direct access to the genetic material from the past could validate these hypotheses and avoid the use of the molecular clock hypothesis.

The Domestication of Cattle: First Insights from Palaeogenetic Studies

Bovine fossils constitute a valuable material for a palaeogenetic analysis, as they are relatively big and compact favouring DNA preservation under certain taphonomic conditions. Furthermore, they constitute a rich body of material allowing for the repetitions necessary to authenticate results as has been discussed above.

Several palaeogenetic studies on cattle domestication processes have been published demonstrating the practicality of the approach (Bailey *et al.* 1996; MacHugh *et al.* 1999; Troy *et al.* 2001). Their analyses show that the sequences obtained from six fossil bones in what are today the British Isles dating from 3,720–12,290 BP cluster tightly in their phylogenetic analysis and are clearly distinct from modern cattle. Thus, this result is in favour of modern cattle populations being exogenous to the British Isles. However, the size of the fossil sampling being so small, no definitive conclusions can be drawn about the presence of Pleistocene lineages from Europe and the Near East in modern *Bos taurus* populations. Palaeogenetic analyses of continental and Near Eastern aurochs populations would shed further light on the domestication process in Europe.

To study the impact of potential local domestication events, numerous or limited in number and geographical area, we have started a palaeogenetic analysis of fossil bovine bones originating from French Neolithic sites. We analysed fossil bones from several Neolithic villages in the Charente region, a region that is characterised by weak hunting activity and a domestication of cattle primarily for traction (Braguier 1999; Burnez *et al.* 1999). Our analyses were performed using a strict protocol for surgical excavations, immediate storage at -20°C, an improved DNA amplification technique (Pruvost and Geigl 2003), and working conditions that satisfied the relevant international standards (*e.g.* Cooper and Poinar 2000)

Our preliminary results show that the Neolithic sequences and the few sequences that we have obtained from aurochs bones of the Charente cluster with the modern Afro-European sequences. Moreover, the ancient sequences are dispersed amongst the modern sequences even when using a phylogenetic method with a relatively high resolution, the 'Median Joining Network' (Bandelt *et al.* 1995). Our preliminary results also confirm the hypothesis of Bailey *et al.* (1996) of a Neolithic expansion of cattle in Europe. In the light of a coevolution and comigration of man and animal, this expansion of animal livestock might be taken as an indication for a dramatic and sustained population expansion of Neolithic farmers, as has been proposed by Troy *et al.* (2001). Moreover, some of our results indicate, in contrast to the situation on the British Isles (Troy *et al.* 2001), that in the Charente local aurochs left genetic traces of their introgression in these cattle herds. We are now extending our analysis to other Neolithic sites in the same and in other geographical areas in order to validate and extent these first results.

Conclusion

As major questions about the when, where, and how of cattle domestication remain unresolved, and as palaeogenetics offers a means to answer them, numerous palaeogeneticists recently started working on ancient bovine material from various geographical regions and time periods. To infer conclusions on the migrations of ancient bovine populations we need precise information about the genetic variation of these populations, which requires the analysis of many bones from many archaeological sites along the presumed migration routes. Moreover, to fully benefit from the power of the palaeogenetic approach, various genetic markers, most importantly on

the nuclear genome, have to be analysed to obtain the resolution needed, which further increases the amount of sample material that must be analysed. In addition, a large sampling size is requested to ascertain the authenticity of the results, since contamination of the samples and fossil extracts constitute a major and serious problem in this field. This may seem unjustified in the eyes of some archaeozoologists who consider the collections of fossil material so precious and irreplaceable that they should not be destroyed for molecular analyses. However, we should not forget that informative biopolymers that are preserved in these fossils also constitute our precious heritage that is, with time, perishing in the collections. The molecular information hidden in a fossil is as precious as its shape and we should undertake collective and concerted efforts to preserve both.

To conclude, the analysis of the migrations of animal and human populations leading to the Neolithisation of Europe involves various disciplines; archaeology, palaeoanthropology, archaeozoology, palaeobotany, palaeogenetics, palaeobiochemistry and molecular phylogenetics. Each approaches this complex issue with its own distinct methods, each of which has its advantages and drawbacks and the potential to contribute in its own way. We would like to plead for each discipline to focus its efforts on the development of their methodologies and analytical capacities. At the same time we would like to emphasise the importance of a close collaboration between these disciplines to elaborate thoughtful and reasonable procedures for the excavation, storage and analysis of fossil material and, most importantly, for an integrated interpretation of the results obtained individually by each discipline.

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4. Zooarchaeology and Agricultural Colonization: an Example from the Colonial Chesapeake

Benjamin S. Arbuckle and Joanne Bowen

This paper presents biometric data of cattle from sites in the Chesapeake region dating to the colonial period, AD 1620–1800. Changes in cattle size were caused by changes in cattle nutrition, which are hypothesized to be related to shifts in the land use strategies employed by colonists. These changes in land use strategies can be modeled in terms of stages of the process of agricultural colonization. It is suggested that size change in domestic animals as well as changes in measures of faunal diversity reported by Miller (1984) may be common zooarchaeological characteristics of the process of colonization by agriculturists.

Introduction

Colonization has been a prominent aspect of human behavior for a very long time. From *Homo ergaster* into Asia 1.8 million years ago, to modern humans in Australia, to the Lapita expansion into Polynesia, to Christopher Colombus in 1492, there are thousands of examples that show that humans are one of the most adept colonizers in the biological world. This paper deals with one very specific example of colonization, that of the Chesapeake region of Eastern North America by Europeans in the 16th, 17th and 18th centuries, and focuses on zooarchaeological data, particularly metrical data from cattle. Changes in cattle size in the colonial period as well as changes in measures of faunal diversity are related to changes in the economy known through documentary and archaeological sources. It is argued that these changes are closely related to the process of colonization by agriculturists and the transition from a phase of colonization proper, to one of establishment and finally intensification.

Methods

This paper examines biometric data from cattle and also reviews data concerning faunal diversity gathered by Miller (1984). Biometric data were collected by Bowen on the remains of cattle (*Bos taurus*) from 17 sites in the Chesapeake region of Virginia, excavated by the Colonial Williamsburg Foundation (Fig. 1). In this paper, 26 different measurements were examined with a sample size of over 1700 individual measurements. Measurements were taken after von den Dreisch (1976) and come from contexts dated between 1620 and 1800. Within this time period five chronological periods are distinguished: 1 = 1620–1660, 2 = 1660–1700, 3 = 1700–1750, 4 = 1750–1775, and 5 = 1775–1800.

The log standard index (LSI) method was used to identify changes in cattle size (see Meadow 1999 for a review of LSI). The LSI method uses a calculation of the difference between log transformed measurements taken of a standard individual, in this case a Jersey bull from the Museum of Comparative Zoology, Harvard University (MCZ # 4), and those from the archaeological population. The measurements of the standard animal are given in Fig. 2. Use of this size index allows measurements from multiple skeletal parts to be combined onto one graph that represents the relationship between the size of the standard animal to that of the archaeological population. The formula used for this transformation is: LSI = log X – log Y, where X is the measurement from the archaeological population and Y is the standard individual. Values less than zero therefore represent measurements smaller than the standard individual, and values greater than zero represent those larger than the standard.

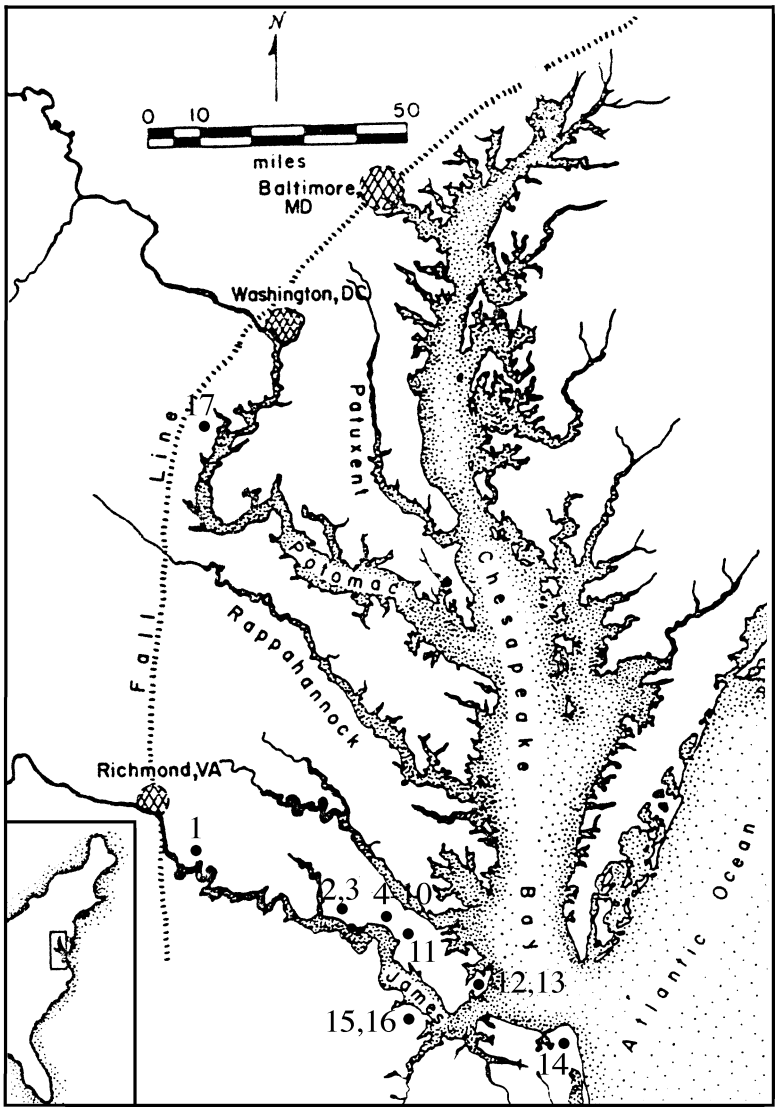

Fig. 1. Map of Chesapeake region and relevant archaeological sites (from Miller 1984, 106).1. Curles Neck Plantation; 2. Rich Neck Plantation; 3. Rich Neck Slave Quater; 4. Peyton Randolph; 5.Brush-Everard House; 6. Grissell Hay; 7. James Geddy; 8. Coffeehouse; 9. Custus House; 10. Shields Tavern; 11. Kingsmill Plantation; 12. Hampton University; 13 Hampton Carousel; 14. Virginia Beach Site; 15. Hornsby; 16. South Grove; 17. Mt. Vernon.

Results

Cattle size was by no means static through the colonial period. The mean size of measurements increased dramatically from period 1, 1620–1660, to period 2, 1660–1700 (see Fig. 3). In period 2, the average size of Chesapeake cattle reached its peak for the entire colonial period. This was followed by an equally dramatic decrease in mean size in period 3, 1700–1750. There was a very slight increase in the size between periods 3 and 4, 1700–1750 and 1750–1775. Average cattle size further declined in period 5, 1775–1800.

Graphs of the maximum, mean and minimum LSI measurements are presented in Fig. 4. These graphs show a peak in both maximum and minimum measurements in period 2, followed by a decline in period 3. The average of the maximum values, representing the size of the largest animals, increase slightly in period 4, and decrease again slightly in period 5. The average of the minimum values, representing the smallest animals, show the same pattern but with greater changes. The minimum measurements decline significantly in period 3, increase slightly in period 4, then finally decline again in period 5.

Discussion

The major influence on these changes in cattle size is likely plane of nutrition. There is no evidence that factors

Element	Measurement	(mm)
Phalanx 1	Bd	30.3
	Bp	36.7
MC III+IV	Bd	66.8
	GL	206.7
MT III+IV	Bp	61.3
Scapula	GLP	79.7
	BG	59.5
Phalanx 2	Bd	27.5
	Bp	33.3
	GL	42.8
Phalanx 3	MBS	23.6
Tibia	Bd	72.8
Astragalus	GLl	70.6
	Bd	48.7
Calcaneum	GL	144.8
	Bd	102
	BT	83.8
	GB	51
Femur	Bd	114.3
	SD	43.5
Radius	BFp	83.9
	Bd	87.7
Ulna	BPC	52.7
Innominate*	LA	76.9
Humerus	Bd	100.2
	BT	81.5

Fig. 2. Measurements of the standard individual used to calculate the LSI. Measurements were taken from a Jersey bull from the Museum of Comparative Zoology, Harvard University (MCZ #4). All measurements are the average between lefts and rights. Phalanx measurements are the average of anterior and posterior.
**The innominate for MCZ #4 could not be located so the LA measurement was taken on a similarly sized individual, MCZ #9.*

such as climate, predation, culling strategy, importation of new breeds and excavation and recovery methods had an impact on this data. That the changes in mean size are representative of a general change in size and not a result of changes in sex and age ratios is supported by Fig. 4. If size changes were the result of changes in the ratios of bulls and cows then these parallel changes in the smallest and largest individuals would not be expected. In Fig. 4, the graphs of the average maximum and minimum measurements from each period parallel the changes in the graph of mean size. This shows that the largest and smallest cattle increased in size in period 2 then decreased in period 3, showing a change in size of the entire population and not simply in the proportions of larger males and smaller females. The changes in size are especially prominent in the minimum values, and shows that the size of the smallest cattle fluctuated more than that of the largest cattle, which was more constant.

Colonization and the Chesapeake

Changes in cattle nutrition are linked to changes in the dominant land use strategies of the Colonial period and to the organization of the general economy. The changes in the economy of the Chesapeake in turn can be viewed in terms of models of the process of agricultural colonization (Miller 1984). We attempt to incorporate the development of Chesapeake land use strategies and of the larger economy with models of the process of agricultural colonization, as this is where we find the best explanation for the fluctuating size of cattle.

Geographers and anthropologists have often outlined the process of agricultural colonization as including stages of *Discovery*, *Migration*, *Colonization*, *Establishment*, and *Intensification* (Diamond 1977; Keegan and Diamond 1987; Graves and Addison 1995). All of these can be incorporated into the development of the Chesapeake colony. For the present purpose the economy of the region in the colonial period can be divided into two generalized systems (after Carr and Menard 1989): the 17th century extensive, long fallow system characterized by a focus on tobacco, and the 18th century diversified system characterized by increasingly intensive agricultural techniques and a wider variety of crops including wheat, barley, hemp, and flax.

The initial stage of *Discovery* took place in the year 1492 with the first voyage of Columbus. *Colonization* was attempted in 1587 with the ill-fated Roanoke colony but not successfully achieved until the founding of Jamestown in 1607. In agreement with models for this stage, stability was tenuous, the colony small and vulnerable to extinction, mortality high, and continued communication with the motherland critical for survival (Andrews 1934; Abbot 1975; Ward 1991). It was not until *c.*1660 that the stage of *Population Establishment* was reached (Simmons 1976; Ward 1991). This stage was characterized by a degree of long-term stability, successful adaptation to local conditions, population growth and expansion, and increased environmental disruption (Diamond 1977; Keegan and Diamond 1987; Graves and Addison 1995).

The early Virginia economy was characterized by scarce labor and abundant land (Simmons 1976). Given these conditions, following the predictions of Boserup (1965), the colonists developed an extensive agricultural system based on long fallow, simple axe and hoe technology, and native crops of tobacco and corn (Carr and Menard 1989; Ward 1991; Percy 1992). The high price of tobacco in the early 17th century spurred a rapid growth in tobacco production, and the system expanded quickly.

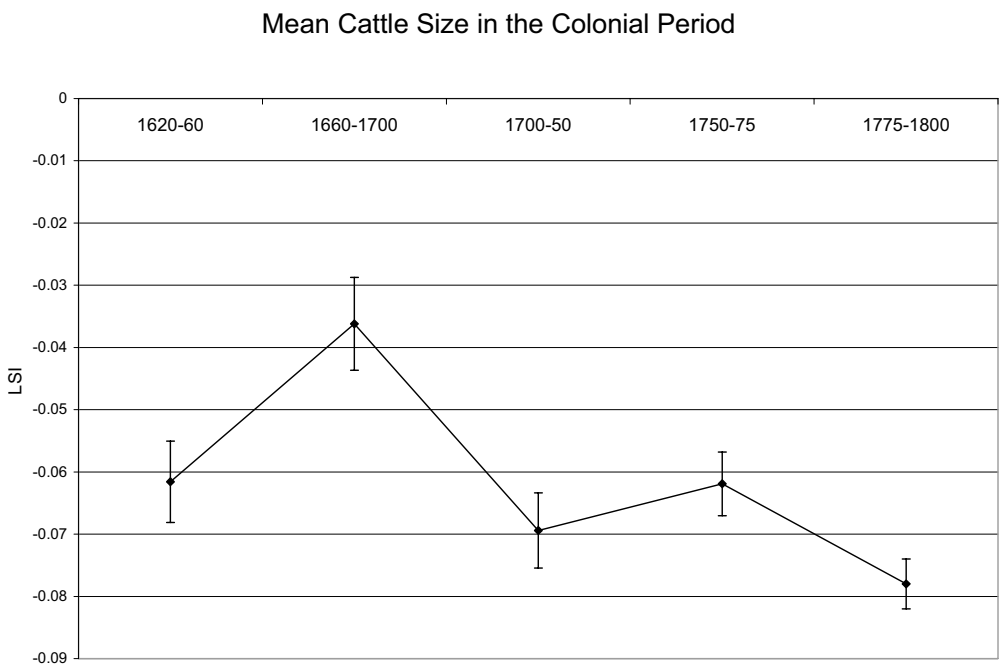

Fig. 3. LSI graph of mean cattle size in the colonial period with 95% confidence intervals.

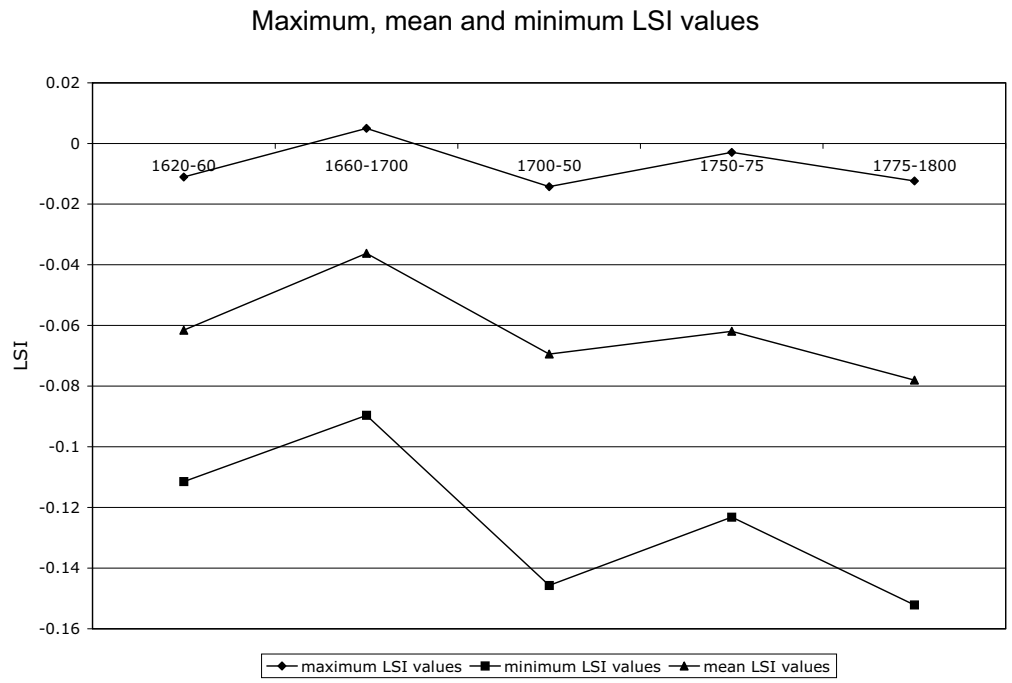

Fig. 4. LSI graph of the maximum, minimum and mean measurements of cattle during the colonial period.

The early 17th century was a time of high tobacco prices, but for the rest of the colonial period planters would find tobacco prices unstable and often subject to volatile changes (Morgan 1976; Risjord 1991; Ward 1991). These troubled times led slowly to the restructuring of the economic system and the emergence of increasing diversification. The early 18th century represents the beginning of the *Intensification* stage of colonization.

This stage was characterized by an increase in population (est. 80–100,000), intensification of land use and subsistence production, and increased independence from the motherland (Miller 1984). As labor became more abundant, and accessible land became less so, planters adopted more intensive land use strategies and invested in crops such as wheat and flax in addition to tobacco (Carr and Menard 1989). In agreement with a model proposed by Green (1977), this agricultural shift took place in the wake of the extensive tobacco system. The extensive system of land use had removed much of the primary forest which allowed more intensive techniques to be effectively utilized in the secondary regrowth forests that were now present. Fields that had been fallow for decades were now planted in European style with furrows, and plows began to replace the hoe and axe technology of the previous century. In the previous *Colonization* and *Establishment* stages intensive wheat cultivation had not been possible. The cultigens themselves were not yet productive in the new environment, trees were many, and labor was in short supply. It was only with the growth of the colony, its population, and an increased impact on the land in the *Intensification* stage that this shift was able to take place.

Effect of Colonization on Cattle Size

The two land use systems described for the colonial period had contrasting impacts on the nutrition and therefore size of cattle. The 17th century extensive system resulted in increased nutrition for semi-feral cattle populations, whereas the 18th century diversified system resulted in decreased nutrition and smaller cattle size.

The long fallow system of the 17th century left little labor for traditional methods of cattle husbandry. As a result, a non-labor intensive animal husbandry system, the Woodland Husbandry System, was developed (Bowen 1997). Under this system cattle were given little care or supplemental feed, and were left to forage for themselves in the woodlands surrounding settlements (Carr and Menard 1989; Ward 1991; Bowen 1991, 1997). The Frenchman Durand remarked after visiting Virginia in 1687 that 'their animals all graze in the woods or on the untilled proportions of their plantations, where they seek shelter nightly rather by instinct than from any care given them' (Bowen 1997, 30).

The extensive tobacco system resulted in an enormous amount of fallow land in the Tidewater. These numerous fallow fields provided cattle with a very productive source of food, and provided planters with productive grazing lands for their cattle with no extra labor expenditure. As a result cattle increased significantly in size through the 17th century.

The development of the 18th century system of diversified production and more intensive land use resulted in a decline in cattle nutrition. At this time fallow periods shortened and the number of fallow fields decreased (Walsh 1989). The result of the combination of diversification and intensification of production of crops for export, but retaining a woodland husbandry system had a detrimental effect on cattle size. Herds of cattle had access to less forage, and nutrition and size decreased significantly in period 3, 1700–1750 and throughout the 18th century.

Zooarchaeology and Colonization

Size change in cattle can be added to several other patterns identified in the faunal remains of the colonial period during the colonization of the Chesapeake. In his dissertation, Henry Miller (1984) noted that faunal assemblages in the Chesapeake from 1620 to 1740 show distinct region-wide trends in faunal diversity, relative frequency of domestic versus wild animals, and even the size of some mollusk species. Miller found that in period 1, measures of species richness in faunal assemblages were high and decreased through periods 2 and 3. This represents a decrease in the number of species exploited in the establishment and intensification phases from a peak early in the colonization phase. The relative frequencies of all wild species, especially deer and fish were high in assemblages in period 1. For example, at early Jamestown 50% of the faunal remains were from wild animals (Miller 1984). This percentage then declined in periods 2 and 3, as the proportion of domesticates in the diet increased (see Fig. 5). At the site of St. Mary's City in Maryland, valve size of the oyster *Crassostrea* was found to be negatively correlated with the human population of the site (see Fig. 6). When the human population was at its largest at around 1690, the oysters were at their smallest, showing the effects of increasing harvesting pressure on the oyster population on a time scale of decades.

These faunal characteristics of colonization are not limited to the Chesapeake region. Similar patterns have been identified, for example, at the site of Hanamiai in the Marquesas, French Polynesia (Rolett 1998). At this site, and at many sites throughout Polynesia, the sequence also shows high faunal richness and a high frequency of wild taxa such as seabirds, turtles, and shellfish in the first decades of colonization (Olson and James 1984; Rolett 1992, 1998; Anderson 1994; Anderson *et al.* 1994; Weisler 1994; Moniz 1997; Kirch 2000). This is followed by a dramatic decline in faunal richness and the frequency of wild taxa as these species decline and subsistence practices shift towards a greater reliance on domesticates. Given the vast temporal, spatial, and contextual differences in between the colonization of the Chesapeake and Polynesia the fact that they share these faunal trends seems to be indicative of a shared underlying process.

One question that comes from comparing faunal assemblages associated with colonization is, can we describe a faunal pattern typical of the process of agricultural colonization, and if we can, can size change be

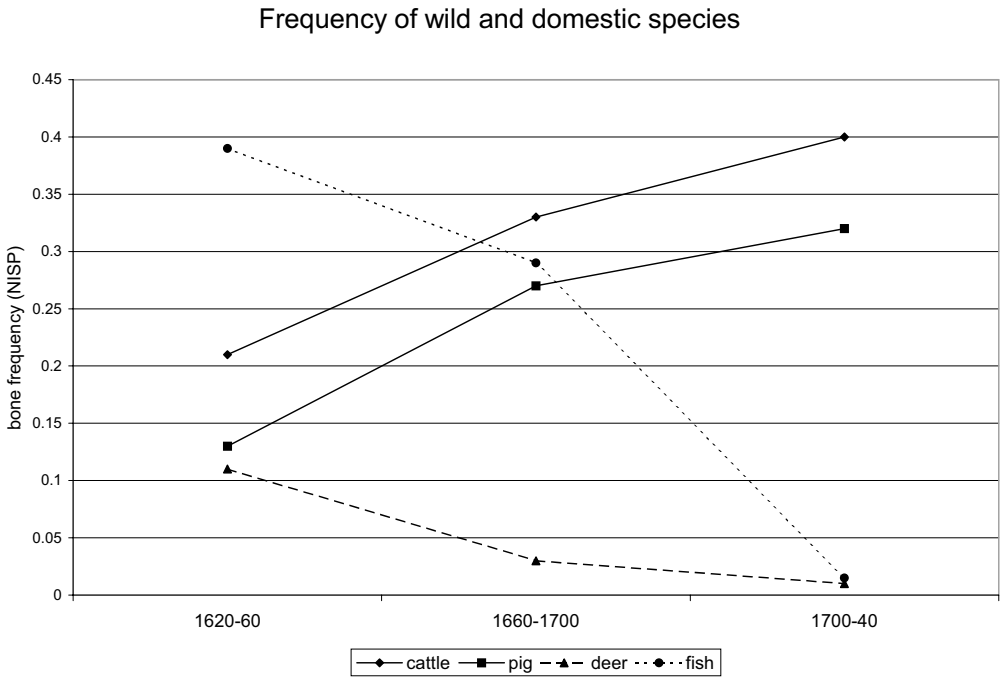

Fig. 5. Relative frequency of wild and domestic animals in the diet in the colonial period Chesapeake based on NISP (data from Miller 1984, 335).

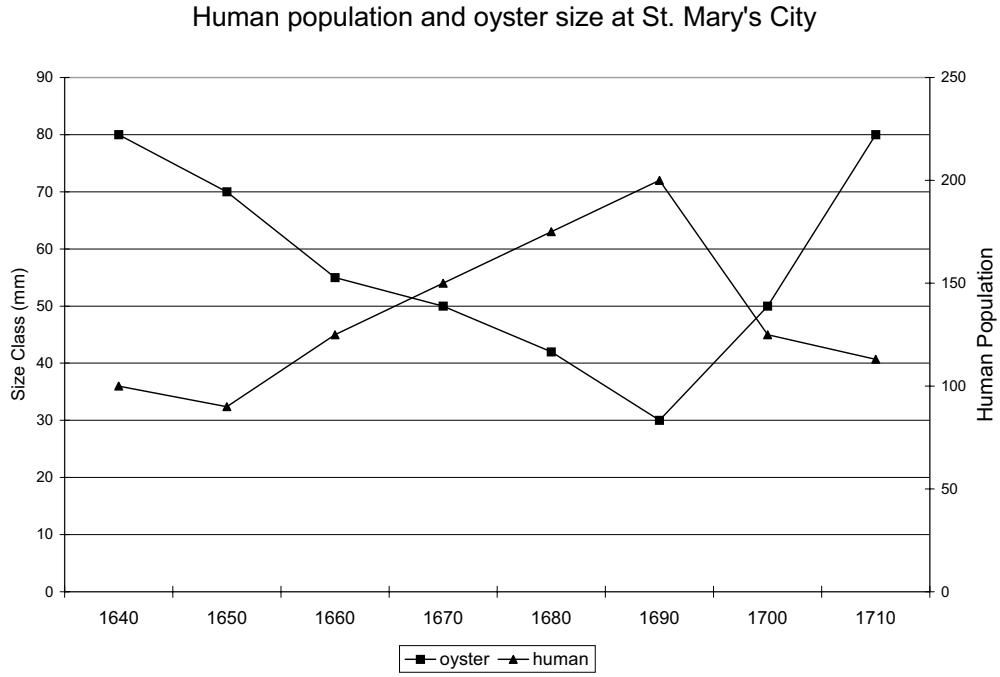

Fig. 6. Graph showing the relationship between changes in the human population and oyster valve size at St. Mary's City, Maryland (data from Miller 1984, 281).

incorporated into this model? Upon initial colonization it is logical (and empirically supported) that native species are often heavily exploited as the small, unstable, colonizing population attempts to gain a foothold in a new environment. These resources are often overexploited and eventually, where it is possible, there is a shift towards greater reliance on domesticates, as crops and animals adapt to the new environment and the land is altered for agricultural use. But there is certainly a great deal of variability in assemblages and this pattern is not always present.

Boserup (1965) and others have given us models that describe the development of agricultural societies in which population growth leads to intensification in land use. It is this shift to intensification in land use that we argue is responsible for size change in cattle in the Chesapeake. Size change may not be correlated with colonization in every case, as there are many courses cultural evolution may take after colonization that do not include a stage of intensification. It seems likely, however, that in instances where intensification does occur that this would have a significant impact on domestic animals and may be identifiable in the biometric data. Further investigation is needed, but it seems that in some cases at least, size change in domestic animals may be added to a general pattern of faunal and environmental change during the process of human colonization. At the very least, size change in animals must be recognized as an important source of information on changes in ecology, productivity, and land use strategies associated with the colonization process.

Conclusion

In this paper changes in the size of Chesapeake cattle are identified between 1620 and 1800. It is argued that size fluctuations were the result of changes in cattle nutrition. These changes were affected by alterations in the land use strategies and lack of change in husbandry strategies in the region as the colony passed through stages of colonization, establishment, and finally intensification. These are some of the first data showing significant fluctuations in the size of an archaeological animal population over such a short period of time. From period 1 to period 2, representing 80 years, mean LSI measures of cattle size increased 41%. From period 2 to period 3, representing less than 100 years, mean LSI measures of cattle size decreased 92%. Similarly, rapid changes in the size of oyster populations have been identified by Miller (1984) at the site of St. Mary's City. It is argued that these size changes, as well as changes in faunal richness and species frequency, reflect general zooarchaeological trends common to the process of agricultural colonization, especially where the intensification phase is reached. This shows that faunal data, instead of being reconstituted as species lists or isolated subsistence data, can be productively incorporated into studies of both short and long term cultural processes and also historical events. Historical archaeology, with its rich textural sources to supplement archaeological data, provides a unique opportunity for precisely incorporating faunal data with the larger patterns of cultural change. It is with this sort of approach that faunal data may be most productively used and incorporated into a meaningful picture of the past.

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5. Modelling Colonisation and Migration in Micronesia from a Zooarchaeological Perspective

Stephen Wickler

Archaeological models of colonisation and migration in Oceania have been increasingly informed by faunal evidence. However, the zooarchaeological literature has focused on Polynesia and Melanesia to a much greater extent than Micronesia. This paper attempts to rectify the situation by reviewing evidence for animals introduced as both intentional and (potentially) unintentional baggage accompanying the initial settlers of Micronesia and subsequent inter-island voyages. By comparing and contrasting the suite of domestic animals (pig, dog and chicken) and prehistorically introduced commensal rat species from archaeological faunal assemblages, clues to disentangling patterns of prehistoric settlement and interaction (and the lack thereof) are sought. Despite considerable problems with reliable identification and chronological control of faunal remains from Micronesian archaeological contexts, this data can shed light on settlement trajectories in western and central-eastern Micronesia and the degree of interaction within and between these two regions.

Models of Colonisation and Migration in Micronesia

In contrast to the widespread demonisation of colonisation and migration studies among archaeologists since the rise of 'New Archaeology' in the late 1960s, Oceanic archaeology has retained its focus on these agents of cultural change as part of a more general fascination with questions relating to origins and the elaboration of culture sequences. This is due in part to the continuing ideological domination of self-professed culture historians among the leading archaeologists in the region. Although the current trend towards the rehabilitation of migration studies (Anthony 1997; Chapman and Hamerow 1997; Burmeister 2000) may have generated renewed interest in a long-standing Oceanic tradition within the larger archaeological community, it tends to take a more critical stance towards the process of modelling population movements.

The general concern with origins in Oceanic archaeology is reflected in approaches to the problem of colonisation and prehistoric migration patterns in Micronesia (Fig. 1). The use of historical linguistics in reconstructing past population movements is another trait of Oceanic archaeology which has played a central role in modelling the Micronesian past. Kirch (2000a) has outlined a linguistic model for the settlement of Micronesia which requires at least a three-part sequence: 1) one or more groups of people moving into western Micronesia directly from island Southeast Asia; 2) a second population or related populations moving into central-eastern Micronesia from the Solomons-Vanuatu region as a northern thrust of the Lapita expansion; and 3) movement of a third population directly from the Bismarck Archipelago into Yap. A fourth movement by Polynesian speakers settling the Polynesian Outlier atolls of Nukuoro and Kapingamarangi has also been documented. Linguistic relationships suggest that the Outlier populations originated from the atolls of the Tuvalu group (Marck 1999). Linguistic evidence lends support to a model in which colonisation of central-eastern Micronesia took place rapidly as indicated by the lack of common development or uniquely shared innovations within Nuclear Micronesian (Bender and Wang 1985).

Although supporting the general sequence and directionality of migrations proposed in the linguistic model, the archaeological evidence remains equivocal with regard to establishing the timing and specific patterns of population dispersals. The first two episodes of migration suggested by the linguistic model are strongly supported

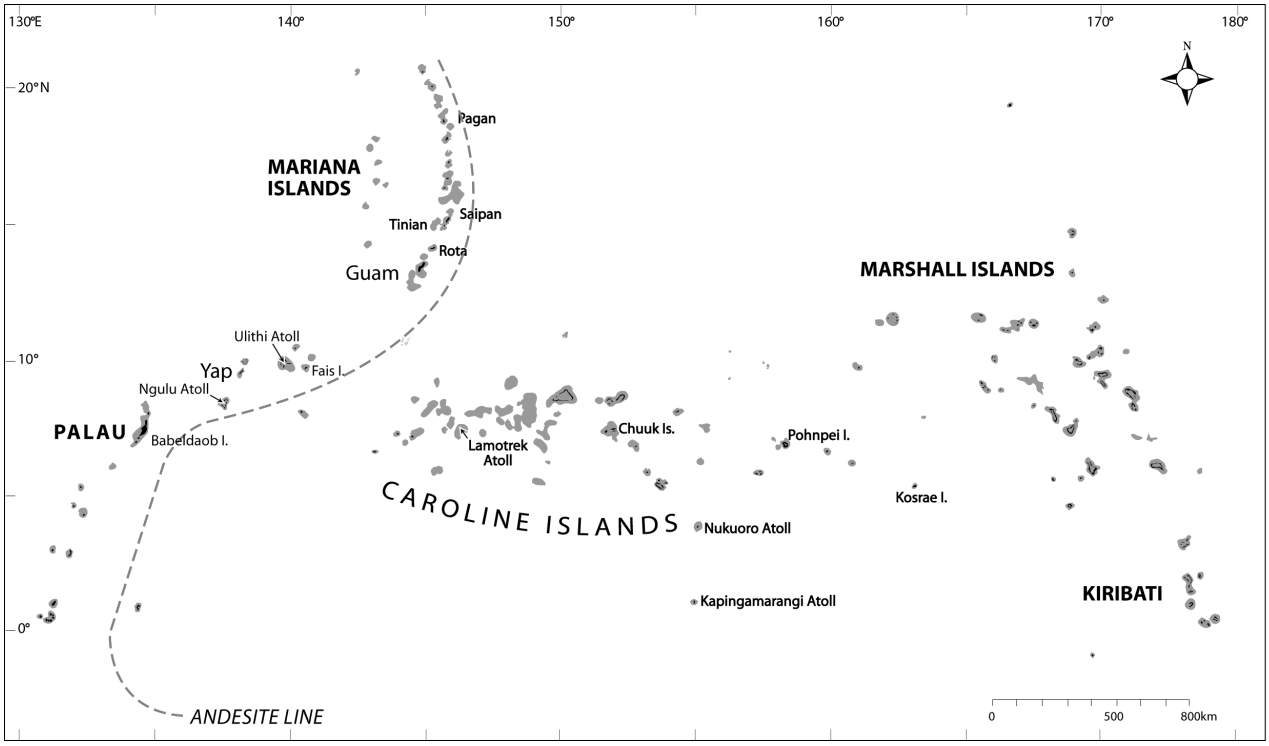

Fig. 1. Map of Micronesia showing locations mentioned in the text.

by the archaeological record and other forms of proxy evidence such as paleoenvironmental data. There is currently no archaeological evidence to support a population movement from island Melanesia to Yap but knowledge of past settlement in Yap is still too sketchy to rule out this possibility. The situation regarding the Polynesian Outliers is still open to debate given the minimal amount of archaeology done in Tuvalu and lack of agreement on the ability of archaeologists to identify Polynesian arrival on the Outliers. Davidson (1992) posits that there is insufficient evidence to determine when Nukuoro became an Outlier while Kirch (2000a) argues that the entire sequence here can be regarded as 'Polynesian'.

It is now generally accepted that the initial settlement of Micronesia involved the movement of Austronesian speaking Neolithic horticulturalists into the western archipelagos from island Southeast Asia (Bellwood 1997; Kirch 2000a). What remains unclear are the points of origin, chronology, and nature of dispersal for these colonising voyages. Various lines of evidence point to an origin in the northern Philippines (Spriggs 1999; Bellwood 2001) and it is clear that the voyages were both intentional and undertaken by skilful seafarers who were capable of successfully navigating open ocean crossings such as the 2,600 km distance between the Philippines and Mariana archipelago. Settlement of the Marianas has been firmly established by the late second millennium BC and most likely occurred sometime before 3500 BP on the basis of archaeological evidence. Recent archaeological evidence from Palau has pushed back the age of initial settlement from 2000 BP to potentially as early as 3500 BP (Welch 2001; Wickler 2001, 2002). There is still no conclusive archaeological evidence for the settlement of Yap prior to 2000 BP.

Recent indirect evidence for human settlement derived from paleoenvironmental coring data in the form of pollen and charcoal particles has necessitated a reappraisal of the archaeological evidence for the colonisation of western Micronesia. The paleoenvironmental evidence suggests that the Marianas were colonised as early as 4800 BP, Palau by around 4500 BP (Athens and Ward 2001) and Yap by 3300 BP (Dodson and Intoh 1999). If these dates are reliable, it may suggest a period of rapid, long-distance dispersal into the western Pacific from island Southeast Asia similar to the spread of the Lapita cultural complex but occurring roughly one millennium earlier (Wickler 2001).

Archaeological evidence from the high islands of Chuuk, Pohnpei, and Kosrae in the central and eastern Carolines confirms settlement by 2000 BP. Citing paleoenvironmental evidence and short-lived pottery use, Rainbird (1995) speculates that initial settlement of Kosrae and Chuuk took place at around 2500 BP in advance of a second wave of colonisers who settled Pohnpei at 2000 BP. Ayres *et al.* (1981) have made a similar claim for pre-2000 BP settlement of Pohnpei based on paleoenvironmental evidence for vegetation burning. However, neither one of these claims for settlement prior

to 2000 BP can be substantiated by archaeological data. Based on pottery attributes and linguistic data, it has been postulated that the source of these settlers was Lapita pottery-using populations in the southeast Solomons or nearby regions (Athens 1990; Kirch 2000a). The degree of interaction between these islands following colonisation remains a topic of debate with Athens (1990) arguing strongly for minimal contact between the major islands and island groups in central Micronesia until at least AD 1100 and perhaps into the historic period.

The earliest reliable dates for settlement on the atolls of the central-eastern Carolines, Marshalls and Kiribati (Gilberts) also cluster at around 2000 BP. Thus the overall evidence for widespread settlement of central-eastern Micronesia at 2000 BP can be viewed as supporting the linguistic model for rapid settlement of this region. Geomorphological data confirms that many of the atolls in this region had yet to emerge and stabilise to the point where they were suitable for human habitation prior to this point in time. Given the marginal environmental resources available on atolls, intermittent visits and temporary use may have preceded permanent habitation in a number of instances in order to create a cultural landscape suitable for settlement.

Atoll colonisation took place over the course of more than one millennium as indicated by the earliest settlement evidence from Lamotrek (*c.* 1000 BP) and Ngulu Atoll (*c.* 1200 BP?) which were probably settled from high islands in western Micronesia. The isolated Polynesian Outlier atolls of Nukuoro and Kapingamarangi appear to have been settled a good deal later than the high islands at 1200 BP and 700 BP, respectively.

Biogeographical Boundaries and Faunal Distribution in Micronesia

There are three principal biogeographic boundaries that have played a significant role in both the distribution of biotas and human settlement of the Pacific. These are the Huxley-Wallace Line, the Andesite Line, and the boundary between Near and Remote Oceania. The first of these boundaries represents a significant water gap from west to east that plants and animals (including humans) had to cross and the second is a geological boundary separating andesite or continental rocks in the west from the oceanic area in the remainder of the Pacific basin. Both fauna and flora are impoverished to the east of the Andesite Line with annual herbs scarce or absent and no vertebrate predators. Both of these boundaries are well known and widely utilised in a number of disciplines.

The third boundary lies between Near Oceania, which includes the island of New Guinea, the Bismarck Archipelago and the Solomon Island chain proper, and Remote Oceania, which encompasses the remainder of Oceania (Green 1991). This distinction is significant in both natural and cultural terms. Near Oceania is the region of greatest biodiversity compared with the markedly diminished marine and terrestrial biotas beyond and also represents the limits of Pleistocene human settlement. Remote Oceania is characterised by a much diminished fauna and flora which decreases with increased distance from Near Oceania and smaller island size, and was first colonised during the mid-Holocene by Neolithic horticulturalists whose ultimate origins lie in island Southeast Asia.

The area currently classified as Micronesia is wholly subsumed within two of the boundaries as it lies to the east of the Huxley-Wallace Line and within Remote Oceania, but straddles the Andesite Line which separates the island groups of western Micronesia from the remainder of Micronesia. The islands of Micronesia have a depauperate fauna and flora typical of Remote Oceania with a range of edible terrestrial fauna essentially restricted to birds, fruit bats, and land crabs combined with a significantly limited selection of edible plants. Thus the inviting images of tropical paradise seen in travel magazines are a far cry from the inhospitable island environments confronted by seafaring colonists. These extreme environments made it necessary for agricultural populations to carry with them everything necessary to insure survival and provide a viable long-term subsistence base. The process of transporting cultural landscapes to newly discovered islands was a hallmark of Oceanic settlement and enabled the successful colonisation of this sea of islands, including the minute atolls which are most characteristic of the 'small islands' of Micronesia.

The domestic and wild animals which accompanied seafaring canoes as both intentional and unintentional baggage were an important component of the 'transported landscapes' brought along on inter-island voyages in Micronesia. The process of animal translocation has a long history in both Near and Remote Oceania with human transport of wild animals between islands in Melanesia since the Pleistocene (Flannery and White 1991).

Prehistoric Distribution of the Triad of Domestic Animals in Micronesia

The three domesticates pig, dog and chicken accompanied agricultural colonists out of island Southeast Asia and into Micronesia and the rest of Remote Oceania. There is a wide range of literature on this process and the distribution of introduced domestic species in Oceania from archaeology and related disciplines. Recent research has focused on the extraction of mitochondrial DNA (mtDNA) from both modern and prehistoric fauna as a means of detailing the origins, directions, and frequency of animal transfers and dispersal in Oceania (Allen *et al.* 2001; Matisoo-Smith and Allen 2001).

A majority of the zooarchaeological literature on faunal introductions in Oceania has focused on Polynesia and Melanesia, with far less attention paid to Micronesia. I

hope to rectify this situation by reviewing the available data on the presence of prehistorically introduced commensal fauna from archaeological contexts in Micronesia. The lack of archaeological excavations or even systematic survey on a significant number of atolls in Micronesia is a handicap but current coverage is adequate to provide reliable data from a majority of the island groups. Other problems include the uneven quality of information on the distribution of faunal remains from Micronesian archaeological sites and the widespread problem of poor chronological control for faunal assemblages within site deposits. Thus my main emphasis will be on simply determining if individual species are present in prehistoric contexts based on a critical assessment of published site reports and other available data. In cases where there is sufficient evidence, I will attempt to say something about the temporal distribution of fauna including dates for both introductions and disappearances from the archaeological record.

Pig

Apart from a lengthy debate concerning the antiquity of pig in Papua New Guinea, most of the literature on pig in Oceania has focused on its cultural importance as an expression of status and prestige and key role in ritual activity. The social centrality of pig overshadows its importance as a food source and both the frequency and quantity of actual consumption is limited in many traditional Pacific societies. Despite the cultural importance of pig, our knowledge of dispersal routes and taxonomic relationships in the Pacific remains limited. A recently initiated study by Allen *et al.* (2001) on the origins and dispersal of Pacific pigs utilising mitochondrial DNA (mtDNA) shows great promise as a means of distinguishing pig taxa represented in complex episodes of introduction, extirpation, and reintroduction which traditional morphological analysis is unable to address. This study has focused for the most part on the spatio-temporal distribution of pig in Polynesia but future work should shed additional light on pig distribution elsewhere in Oceania.

Intoh (1986) attempted to document the distribution of pig in Micronesia on the basis of historical documents and archaeological evidence. She used written sources and linguistic data to document the post-European introduction of pig, which was unknown throughout Micronesia at western contact. Intoh also reviewed the results of archaeological investigations available at the time and found no convincing evidence for the presence of prehistoric pig apart from Masse *et al.*'s (1984) report of pig bone from secure contexts in Palau and the recovery of a single pig tooth from the Sabaig site on Lamotrek Atoll by Fujimura and Alkire (1984). The Lamotrek evidence is disputed by Athens (pers. comm.) who has identified the alleged pig tooth as coming from a fish (Fig. 2).

Based on excavation results from the raised coral island of Fais in the western Carolines, which has a land area of only 2.8 km^2, Intoh (1996) has claimed that pig is found throughout the prehistoric sequence which begins at around AD 200. Fais is also the only island in Micronesia where the presence of all three domestic animals has been reported from prehistoric archaeological contexts. As the amount of pig bone, its stratigraphic context, and association with radiocarbon dates remains unpublished, it is difficult to trace the temporal distribution of pig on Fais.

The presence of prehistoric pig has been confirmed in multiple locations from archaeological excavations in Palau. Remains of three to four young pigs were found in the early cultural horizon at the Uchularois Cave site in the Rock Islands dating to AD 650–900 (Masse 1990). Pig bone was also associated with midden deposits from a nearby village site on Ngemelis Island with a calibrated date of AD 1250–1345. Additional pig bone has recently been recovered from archaeological deposits at Ngimis Village on Babeldaob Island as part of the Compact Road project. Test excavations in 1996 by Wickler (Wickler *et al.* 1997, 267) produced pig remains from several individuals in a shell midden deposit. Additional excavations at this location in 1997 yielded bones from a subadult pig within the same shell midden, including a metapodial with cut marks (O'Day 1999, 112–113). Two radiocarbon dates with a calibrated 2 sigma age range of AD 1300–1630 were obtained from a cultural stratum directly underlying the midden (Layer II), which also had a limited amount of (intrusive?) pig bone in the upper portion. A radiocarbon sample from a substratum overlying the midden deposit with evidence of historic disturbance (Layer Ia) produced a modern date. As the midden deposit (Layer Ib) has yet to be directly dated, the age of the pig bones remains uncertain although they appear to predate western contact based on the absence of non-indigenous material in the deposit. Direct dating of the pig bone in question may resolve this issue.

If the pig remains from Ngimis date to the late prehistoric period and pigs were no longer present at western contact as suggested by their absence in accounts written by the first European visitors (Keate 1788), this suggests that pigs were extirpated not long before the first recorded contact with Europeans in 1783. Alternatively, the pig remains at Ngimis may date to the proto-historic or early historic period thus raising the possibility that pigs were actually present at contact and their absence in early accounts is due to oversight or lack of knowledge as argued by faunal analyst O'Day (1999, 113). If this is the case, it strikes me as odd that Keate's remarkably rich ethnohistorical account of the three month stay of Capt. Wilson and the other survivors of the *Antelope* shipwreck in Palau would neglect to mention pigs but remark on the presence of fauna such as fowl and rats.

Evidence from elsewhere in Oceania for the extirpation of pigs indicates that island size was a key factor and extinctions usually occurred on islands under 50 km^2 (Bay-Petersen 1983). Kirch (2000b) argues that instances of

Archipelago / Island	Pig (*Sus scrofa*)	References	Comments
Western Micronesia			
Marianas	No		
Palau	Yes	Masse 1990; Wickler *et al.* 1997; O'Day 1999	Earliest presence at AD 650-900 in Uchularois Cave deposits with apparent extirpation prior to western contact.
Yap	No		
Fais	Yes	Intoh 1996	Presence claimed throughout the prehistoric settlement sequence, but data do not appear to be secure.
Central-Eastern Micronesia			
Lamotrek (central Carolines)	?	Fujimura and Alkire 1984; Intoh 1986	Based on a single tooth dated to around AD 1200-1300. This finding is disputed by Athens (pers. comm.), who believes the tooth is most likely from the fish *Pseudobalistes* sp.
Chuuk	No		
Pohnpei	No		
Kosrae	No		
Marshalls	No		
Kiribati	No		
Polynesian Outliers			
Nukuoro	No		
Kapingamarangi	No		

Fig. 2. Evidence for the distribution of pig prior to western contact in Micronesia.

purposeful pig elimination late in the prehistoric sequences on Tikopia, Mangaia, and apparently Mangareva as well, are linked to environmental and economic factors. These factors include small island size and isolation, high human population density, and intensive resource competition leading to persistent social strife and ultimately direct trophic competition between man and pig. This argument is less plausible in the case of the Palau archipelago which includes Babeldaob, a 333 km^2 island that is the second largest in Micronesia. As Masse (1990, 222) states, the extirpation of pig in Palau is unique in prehistoric Oceania for any island group so large and environmentally diverse.

The collective evidence for prehistoric pig in Micronesia is thus extremely limited with its confirmed presence restricted to the large island group of Palau and the small island of Fais. Why do pigs only appear at these two locations in all of Micronesia? The argument that scarce resources prohibited the successful introduction of pigs is difficult to support when one considers the absence of pigs on large islands where there has been extensive archaeological excavation, such as Guam, Pohnpei and Kosrae, coupled with the claimed presence of pig during most of the settlement sequence on the tiny island of Fais, which is significantly smaller than Tikopia (although evidence demonstrating the early establishment of pig here has yet to be published).

The Micronesian situation is unlike that of Polynesia where pig remains are dispersed across a wide area in early contexts, albeit in small numbers. Polynesian pig distribution in later prehistoric contexts is patchy with cases where pig husbandry was never successfully established or where it was established but disappears from the archaeological record at some point during the prehistoric period (Allen *et al*. 2001).

Dog

As shown in Fig. 3, dog remains from prehistoric archaeological contexts have been recorded across much of central-eastern Micronesia. The most secure evidence comes from Pohnpei, Kosrae and the Marshall Islands. Dog remains were identified in the earliest deposits at Nan Madol in Pohnpei securely dated to about AD 1 and dogs were also present at contact. Athens (1990, 29) uses evidence for the intentional human transport of dog to support his argument that the colonisation of central Micronesia was a result of purposeful voyages of discovery from island Melanesia without intermediate stops or island hopping en route. A total of three radiocarbon dates (using the XAD resin process) on dog bone from archaeological excavations at the Katem compound on Lelu in Kosrae confirms the presence of dog at around AD 900 (Athens 1995; Athens *et al.* 1996). Weisler (2001a, 2001b) has documented the presence of dog by around AD 1100 on Utrök Atoll, a marginal location situated near the northern limit of permanently-inhabited atolls in the Marshall Islands. Dog has been documented in prehistoric contexts at other locations in the Marshalls and was present at contact. Although the prehistoric presence of dog at around AD 1400 has been claimed from excavations by Takayama *et al.* (1985) on Makin in the Gilbert Islands (Kiribati), the reliability of this date is questionable.

Dog remains elsewhere in the central Carolines are meagre, but the prehistoric presence of this domesticate has been argued on the basis of archaeological evidence from both Fefan in Chuuk Lagoon and Lamotrek. The Fefan remains are restricted to a single phalange from a pottery-bearing deposit at Nepi potentially dating to

Archipelago / Island	Dog (*Canis familiaris*)	References	Comments
Western Micronesia			
Marianas	No		
Palau	No		
Ngulu	?	Intoh 1984; Intoh 1996	Complete skeleton of a small dog tentatively dated to *c.* AD 1300.
Yap	No		
Fais	Yes	Intoh 1996; cf. Intoh 1999	Presence of dog claimed throughout the prehistoric sequence (Intoh 1996), but existence during the earliest phase of settlement at around AD 200 should be regarded with caution (Intoh 1999).
Central-Eastern Micronesia			
Lamotrek (central Carolines)	?	Fujimura and Alkire 1984	Two teeth from a pottery-bearing deposit at the Bolipi site potentially dating to *c.* AD 1600.
Fefan (Chuuk)	Yes	Shutler *et al.* 1984	A single phalange from a pottery-bearing deposit at the Nepi site possibly dating to *c.* AD 700.
Pohnpei	Yes	Athens 1990	Found in the earliest pottery-bearing deposits at Nan Madol dating to *c.* AD 1 and in later site deposits but not at contact.
Kosrae	Yes	Athens 1995, Athens *et al.* 1996	Prehistoric presence confirmed archaeologically with multiple prehistoric radiocarbon dates directly on bone as early as AD 900.
Marshalls	Yes	Weisler 2001a, 2001b	Introduced by at least AD 1100s on Utrök Atoll.
Gilberts (Kiribati)	?	Takayama *et al.* 1985	Presence claimed in a site deposit on Makin dated to *c.* AD 1400 but reliability of dates is questionable.
Polynesian Outliers			
Nukuoro	Yes	Davidson 1971, 1992	The earliest date for settlement is *c.* AD 800 from a dog tooth. Dog is abundant in early deposits but disappears by *c.* AD 1500.
Kapingamarangi	No		

Fig. 3. Evidence for the distribution of dog prior to western contact in Micronesia.

around AD 700 based on a single charcoal radiocarbon date (Shutler *et al.* 1984). The identification of this bone as pig has been confirmed by faunal specialist Sarah Collins (Athens 1990, 29) and its association with pottery suggests a date prior to AD 1100. The prehistoric age of the Lamotrek remains, consisting of two teeth from a site deposit at Bolipi with imported Yapese pottery potentially dating to *c.* AD 1600 (Fujimura and Alkire 1984), is uncertain given the disturbed nature of the site and questionable accuracy of the bone and shell dates obtained from the deposits.

The early presence of abundant dog remains on the Polynesian Outlier of Nukuoro has been confirmed through direct dating of bone providing the earliest age estimate for settlement at around AD 800 (Davidson 1992). In contrast, there is no evidence for dog in archaeological contexts from the Outlier atoll Kapingamarangi.

Evidence for prehistoric dog in Micronesia to the west of the Andesite Line has only been found on two islands near this boundary. Intoh (1996) claims that dog remains are present throughout the prehistoric sequence on Fais. As with the pig evidence from Fais, the distribution of dog remains and their association with radiocarbon dates has yet to be published and is therefore difficult to assess. Intoh (1999) herself has stated that the evidence for dog during the earliest phase of occupation must be treated with caution. There is also potential evidence for prehistoric dog from Ngulu Atoll where the complete skeleton of a small dog has been tentatively dated to AD 1300 based on its stratigraphic relationship with a *Tridacna* shell date. Dog was not recorded on Ngulu at contact.

In addition to the potential loss of dog on Ngulu, prehistoric extirpation of this animal has been documented on the high island of Kosrae where dog is restricted to relatively early prehistoric deposits on Lelu and absent at contact (Athens 1995; Athens *et al.* 1996) and the Polynesian Outlier of Nukuoro where it disappears from the archaeological record at about AD 1500 (Davidson 1971, 1992).

The contrast between the widespread presence of prehistoric dog on islands to the east of the Andesite Line and the minimal occurrence of dog to the west of this boundary appears to reflect significant patterns in prehistoric population movements. The complete absence of dog remains from prehistoric archaeological contexts in the three major archipelagos of western Micronesia suggests that dogs either did not accompany colonising groups arriving from island Southeast Asia or did not survive the voyage. The lack of remains in later prehistoric site deposits can also argue for continuing isolation from island groups with dogs to the east, apart from the probable introduction of dog to Fais and Ngulu from the central Carolines. The continued absence of dog is also likely to reflect cultural choices.

Active networks of prehistoric exchange and interaction straddling the Andesite Line were in place during

the second millennium AD as indicated by the well documented ethnographic *sawei* long-distance communication and exchange system stretching 1,200 km from Yap eastward to Pulawat (Hunter-Anderson and Zan 1996; D'Arcy 2001). Archaeological evidence of inter-island exchange includes the importation of Palauan pottery to Ngulu and Fais (via Yap?) and Yapese pottery to Ngulu, Ulithi, Fais and Lamotrek (Dickinson and Shutler 2000).

The widespread distribution of prehistoric dog in central-eastern Micronesia and its presence during the earliest phase of settlement on several islands demonstrates that colonising populations purposefully included dogs as a component of their transported landscapes on long-distance inter-island voyages. The somewhat uneven distribution of dog and evidence for prehistoric extirpation in this region resembles patterns observed for pig, and potentially dog as well, in Polynesia.

Chicken

The prehistoric distribution of chicken in Micronesia is more difficult to document than dog and my review of the literature revealed only four cases with confirmed or potential evidence for chicken in prehistoric archaeological deposits. The accuracy of this distribution pattern is unclear due to problems with the identification of bird bone to the species level and potential biases against the recovery of microfaunal remains introduced by excavation and sorting methods.

Data on the distribution of chicken remains in archaeological sites on Fais has been published in detail by Steadman and Intoh (1994). Chicken is by far the most common species of bird in all four sites on Fais and chicken bones were present throughout the stratigraphic sequences. However, chicken remains are scarce in the earliest levels leading to the suggestion that chickens were less abundant than native birds during the initial phase of settlement as reported from early site deposits in Polynesia (Steadman and Intoh 1994, 130). Steadman has also reported the presence of chicken as a component of the prehistoric avifauna in Pohnpei (Steadman *et al.* (n.d.) in Steadman and Intoh 1994, 133). Unfortunately, no details are provided as to the specific site locations from which this data was obtained. Lamotrek Atoll (Fujimura and Alkire 1984) also has potential evidence for prehistoric chicken as bones were found scattered through the stratigraphic sequences in excavations at Sabaig (748 g total) and Bolipi (190 g total). Although the remains were found in levels interpreted as dating to the prehistoric period, problems with site disturbance and the accuracy of radiocarbon dates indicate that direct dating of chicken bone will be required for a reliable age assessment. The presence of chicken bone is reported from archaeological excavations on Kapingimarangi by Leach and Ward (1981) in contexts which may be prehistoric but lack secure dating. Indirect evidence for the presence of prehistoric chicken can be gleaned from historic accounts which indicate that chickens were present at western contact on Palau (Keate 1788) and Kosrae (Athens *et al.* 1996).

In summary, the distribution of chicken at western contact in central-eastern Micronesia appears to exhibit the same patchy pattern as dog although its presence is not as widespread. In western Micronesia prehistoric chicken has a similar distribution as pig and is restricted to Palau and Fais, although evidence of prehistoric chicken remains from archaeological site contexts in Palau appears to be lacking. There is no evidence for the disappearance or purposeful elimination of chickens in Micronesian prehistory and this may relate to the fact that chickens are both smaller and less important culturally than either pig or dog. Husbandry of chickens in traditional Pacific societies is rather loose and animals often exist in a semi-feral state as free-roaming scavengers. They are not an important food source and eggs are seldom eaten. The main use for the birds is often the production of feathers for decoration (Baldwin 1990).

Does Size Matter? Exploring the Prehistoric Distribution of Commensal Rat Species in Micronesia

Two species of commensal rat were introduced to Micronesia by prehistoric populations in addition to the triad of domestic animals. The smaller of the two, the Pacific rat (*Rattus exulans*), is distributed throughout the insular Pacific (Tate 1935; Wodzicki and Taylor 1984; Roberts 1991).

There is continuing debate as to whether the Pacific rat was intentionally transported on prehistoric inter-island voyages or if its presence was purely a matter of chance. The most widely circulated theory has been that rats accompanied canoe voyages as inadvertent stowaways (Kirch 2000a, 59). A variant on this theme is the hypothesis that rats may have been transported on canoes that had lost their human crew (Anderson 1996). The counter-argument is that rats were transported intentionally as a food source (Roberts 1991; Matisoo-Smith 1994), supported by ethnographic evidence for rat consumption from a number of Pacific islands (e.g. Tonga, Mangaia and New Zealand). Matisoo-Smith (Matisoo-Smith *et al.* 1998, 1999; Matisoo-Smith and Allen 2001) has been a vocal advocate of intentional transport and cites the ubiquitous presence of the Pacific rat in support of her argument in agreement with Tate (1935).

An alternative view which should be considered is that the ubiquitous presence of *R. exulans* actually *supports* accidental transport in contrast to the irregular or patchy distribution of other 'wild' animals and the triad of domestic animals in Oceania known to reflect intentional transport and a process of cultural selection. The culturally non-selective nature of unintentional rat transport and the potential for multiple voyages between

Archipelago / Island	Chicken (*Gallus gallus*)	References	Comments
Western Micronesia			
Marianas	No		
Palau	Yes	Keate 1788	Recorded at western contact.
Ngulu	No		
Yap	No		
Fais	Yes	Steadman and Intoh 1994	The most common bird species in site deposits and present throughout the prehistoric settlement sequence.
Central-Eastern Micronesia			
Lamotrek (central Carolines)	?	Fujimura and Alkire 1984	Bone in site deposits at Bolipi and Sabaig but uncertain of prehistoric context.
Fefan (Chuuk)	No		
Pohnpei	Yes	Steadman *et al.* (n.d.) cited in Steadman and Intoh 1994	Reported as a component of the prehistoric avifauna from Pohnpei.
Kosrae	Yes	Athens *et al.* 1996	Presence reported at western contact but not documented archaeologically.
Marshalls	No		
Gilberts (Kiribati)	No		
Polynesian Outliers			
Nukuoro	No		
Kapingamarangi	?	Leach and Ward 1981	Reported as possibly prehistoric.

Fig. 4. Evidence for the distribution of chicken prior to western contact in Micronesia.

islands over time increases the likelihood that rat populations would be successfully established and spread across a wide area.

The claim that *R. exulans* occurs on *every* Pacific island settled by humans (White *et al.* 2000) must be reconsidered on the basis of uneven rat distribution in Micronesia (Fig. 5). Reliable evidence for the presence of *R. exulans* in the prehistoric archaeological record is limited to the Marianas in western Micronesia, and Pohnpei, the Marshalls and the Polynesian Outliers of Nukuoro and Kapingimarangi in central-eastern Micronesia. The presence of prehistoric Pacific rat on the Outlier atolls has been confirmed by mtDNA analysis (Matisoo-Smith pers. comm.). Remains of this species also appear to be present in prehistoric deposits from Palau and Kosrae but this has yet to be confirmed. Unidentified rat bones which may be *R. exulans* have been recovered from archaeological sites in Chuuk and on Ngulu but their age is uncertain. The apparent absence of Pacific rat in site deposits at other locations including the Gilberts, Lamotrek and Yap may reflect a lack of published site reports as well as inadequate collection and taxonomic identification of small rodent remains.

Although the available evidence from Micronesia documents a patchy distribution for *R. exulans* rather than supporting a universal distribution model, there are too many gaps and uncertainties in the faunal data to determine if this pattern is real. However, the evidence does *not* support Flannery's (1995, 50) assertion that the arrival of *R. exulans* in Micronesia appears to date to the European period although this may be the case on some islands as Intoh (1996) reports for Fais. It is also noteworthy that this species does not appear in the archaeological record of the Marianas prior to AD 1000–1200 (Steadman 1999), roughly coinciding with the start of the Latte Period. The evidence for introduction of *R. exulans* relatively late in the prehistoric sequence is intriguing and may represent a more widespread pattern in Micronesia. If this proves to be the case, it suggests a very different situation than that observed elsewhere in Oceania and one more likely to reflect cultural choice rather than chance or accident.

The presence of a second prehistorically introduced rat species in Micronesia, the Asian house rat (*Rattus tanezumi* (Temminck, 1844) – sometimes referred to as *Rattus rattus mansorius*), provides insights into patterns of human colonisation and migration and sympatric relationships between rodent species. *R. tanezumi* is an Asian relative of *Rattus rattus* (Black Rat) that is larger than the Pacific rat and has a spotty prehistoric distribution like that of the domestic fauna. Due to a lack of clarity in the available evidence, the presence of this rat in prehistoric site deposits can only be confirmed on Fais, Pohnpei and Nukuoro. Its existence is also likely in the Marianas, Palau, Ngulu and Chuuk. Much of the distributional information is summarised in a brief overview by Flannery (1995, 50) in which the presence of rat bones in archaeological sites is mentioned at all of the above locations except Palau. He also states that this species has been present for more than one thousand years in Micronesia but provides no dates for individuals islands.

The earliest record of Asian rat is from Fais where Intoh (1996, 1999) has documented its presence from

Archipelago / Island	Pacific Rat (*Rattus exulans*)[1]	Asian House Rat (*Rattus tanezumi* or *R. rattus mansorius*)[2]	References	Comments
Western Micronesia				
Marianas	Yes	?	Flannery 1995; Steadman 1999; White n.d.;	*R. exulans* absent in site deposits older than *c.* AD 1000–1200 (Steadman 1999). *R. tanezumi* present in archaeological sites from Pagan, Rota, and Guam (Flannery 1995). Both species present in site deposits from Pagat, Guam (White n.d.).
Palau	?	?	Masse 1989, 1990	Remains of two rat species in Uchularois Cave deposits dating to AD 650-900, probably *R. exulans* and *R. rattus mansorius.*
Ngulu	?	?	Intoh 1981; Flannery 1995	Unidentified rat bones reported in archaeological deposits (Intoh 1981). *R. tanezumi* recovered from an archaeological context (Flannery 1995).
Yap	No	No		
Fais	No	Yes	Intoh 1996, 1999	*R. tanezumi* found from the earliest deposits throughout the cultural sequence while *R. exulans* was only recently introduced
Central-Eastern Micronesia				
Lamotrek (central Carolines)	No	No		
Chuuk	?	?	Takayama and Seki (n.d.); Takayama and Intoh (n.d.); Flannery 1995	Rat bones from archaeological sites on Tol Atoll that appear to be from *R. tanezumi* (White and Flannery n.d.). *R. tanezumi* recovered from an archaeological context (Flannery 1995).
Pohnpei	Yes	Yes	Ayers *et al.* 1981; Flannery 1995; Intoh 1999; Athens (unpublished data)	Rat remains including *R. tanezumi* from a test pit on Imwinyap Islet, Ant Atoll with a basal date of *c.* AD 900 (Ayers *et al*. 1981; Flannery 1995). *R. exulans* and another rat documented by *c.* AD 1400 at the Nan Madol site on main island (unidentified rodent in earlier deposits) (Athens unpublished data).
Kosrae	?	No	Athens 1995	*R. exulans* distributed throughout the archaeological deposits at Katem, Lelu but not possible to confirm presence prior to western contact.
Marshalls	Yes	No	Weisler 2001b	No directly associated dates but depth of some bones point to a prehistoric introduction on Utrök Atoll.
Gilberts (Kiribati)	No	No		
Polynesian Outliers				
Nukuoro	Yes	Yes	Davidson 1971; Flannery 1995	Two sizes of rats identified in prehistoric archaeological deposits: *R. rattus mansorius* and *R. exulans*
Kapingamarangi	Yes	No	Leach and Ward 1981	Only *R. exulans* in archaeological site deposits

[1] *Rattus exulans* has been recorded historically from both Yap and Fais where prehistoric evidence is currently lacking.
[2] *Rattus tanezumi* recorded historically from Palau, Guam, Chuuk and Pohnpei (Johnson 1962).

Fig. 5. Evidence for the distribution of commensal rat species prior to western contact in Micronesia.

earliest settlement throughout the prehistoric sequence. Despite problems with secure archaeological contexts and temporal control, it is reasonably certain that the Asian rat was widely distributed elsewhere in western Micronesia as supported by its presence during the historic period. In Palau, Masse (1990, 221) reports that frequent elements of at least two species of rats were found in the early horizon at the Uchularois Cave site dated to AD 650–900. He also asserts (Masse 1989, 52) that rats recorded at contact (Keate 1788) would have included at least two different species (probably *Rattus rattus mansorius* and *Rattus exulans*) on the basis of archaeological evidence. Flannery (1995) reports the presence of *R. tanezumi* remains from archaeological sites on the islands of Pagan, Rota and Guam in the Marianas and Ngulu Atoll in Yap but provides no further details. The basis for this claim is data from an unpublished report (White and Flannery n.d.) on remains from Fais which also mentions the *possibility* that *R. tanezumi* is present based on a review of archaeological reports from the Marianas and Ngulu. A second unpublished report (White n.d.) confirms the presence of two distinct species of rat in all levels at the Pagat site on Guam but no dates for this site are provided. According to White, comparisons with rat remains from other Micronesian sites clearly show that these species are *R. exulans* and *R. tanezumi.*

In Pohnpei, remains identified as Asian rat appear in archaeological deposits from Ant Atoll (Ayres *et al*. 1981; Flannery 1995) and are also likely to account for an unidentified rat species found in association with *R.*

exulans by AD 1400 at Nan Madol (Athens unpublished data). Asian rat remains are also present in prehistoric deposits on Nukuoro where this species appears to be sympatric with *R. exulans* (Davidson 1971). According to White and Flannery (n.d.), illustrations of unidentified rat remains from excavations on Tol Atoll in Chuuk (Takayama and Intoh n.d.; Takayama and Seki n.d.) appear to be from *R. tanezumi* as they are too large for *R. exulans*.

The uneven distribution pattern for *R. tanezumi* suggests intentional transport of a wild animal, potentially as a supplemental food source, in the same manner as domestic species thus blurring the common distinction between these two categories in terms of intentionality. This disjunct pattern resembles that of *Rattus praetor* which was translocated beyond the '*exulans* only' boundary at Tikopia into Remote Oceania as far east as Fiji in prehistory, although it is no longer found there (White *et al.* 2000).

What can the prehistoric distribution of *R. tanezumi* tell us about potential migration patterns in Micronesia? Its widespread distribution in western Micronesia suggests introduction by colonising populations directly from island Southeast Asia. Intoh (1997, 1999) has cited the distribution of Asian rat in central Micronesia as supporting evidence for her model of Micronesian settlement involving migration from Palau and Yap along the Caroline chain as far eastward as Pohnpei. But neither the linguistic data nor archaeological evidence, including the distribution of other introduced fauna, convincingly support this model. There is also a substantial gap in the distribution of *R. tanezumi* between Fais and Chuuk which requires explanation. This gap poses a problem in tracing the dispersal of this animal east of the Andesite Line as it is difficult to determine if the known distribution in central Micronesia is a reliable indicator of contacts between islands or reflects deliberate decisions by prehistoric populations about rat transport which may mask actual inter-island connections.

The documented sympatric relationship between *R. tanezumi* and *R. exulans* during prehistory may also shed light on patterns of rat dispersal and inter-specific relationships. Competition between species can be an important factor in determining distribution patterns and it has been suggested that the presence of *R. tanezumi* in Micronesia prevented the establishment of *R. rattus* there (Johnson 1962). Thus *R. tanezumi* may have occupied the niche currently held by *R. rattus* in relation to *R. exulans* elsewhere in Remote Oceania. In this vein, it is interesting to note that *R. tanezumi* is currently present in Fiji, where it is sympatric with *R. rattus* (Flannery 1995).

In reviewing evidence for the prehistoric introduction of rat species in Micronesia, it has become clear that a much more thorough and systematic analysis of rat remains must be undertaken if we are to piece together the rat puzzle. The task of documenting rat distribution is compounded by difficulties in distinguishing rat species by morphological analysis of limited archaeological skeletal remains that are often poorly preserved and badly fragmented. Thus it is imperative that sufficiently large assemblages of rat bone are available if we are to go beyond the level of distinguishing rats on the basis of gross size differences especially given the high degree of size variation in *R. exulans* which overlaps with other species. Developments in the genetic identification of rat species through mtDNA analysis coupled with direct dating of rat bone offer significant potential for tracing the prehistoric human dispersal of murids across Micronesia and the rest of the Pacific and should be actively pursued.

Discussion and Conclusions

Before examining potential factors responsible for the uneven distribution of the domestic animal triad and rats in Micronesia, it is important to consider the possibility that deficiencies in the archaeological record account for the perceived absence of particular species across Micronesia. Although archaeological excavations on quite a few islands are either nonexistent or limited in scope, sufficient work has been done on a majority of the larger islands to provide a fairly reliable basis for evaluating the faunal record. This is especially true in the Marianas where numerous excavations have been conducted over the past several decades. It is thus noteworthy that there continues to be no evidence for domestic animals prior to western contact in this island group. Evidence for patchy distribution of introduced animals in Polynesia where excavations are far more extensive also supports the conclusion that this pattern is real throughout Remote Oceania.

If we accept that the discordance in distributions of domestic animals across Micronesia is real, the most convincing explanation for this pattern must lie in the complex realm of social practice in which cultural decisions were made within the context of specific island environments. As White (2001) has pointed out, it is the absences of domestic animals in particular areas that requires explanation. Human colonists actively manipulated both the physical and social aspects of their transported landscapes in order to satisfy cultural agendas which defy simplistic economic or adaptive explanatory frameworks grounded in western concepts of rationality.

This interpretation is strengthened by the fact that distribution patterns of introduced fauna are at odds with the biogeographical tenet that faunal diversity diminishes with island size. The total absence of domestic fauna on Guam, the largest island in Micronesia, does not support the argument that either the establishment of breeding populations was unsuccessful or that species were wilfully extirpated predominantly on small islands where they competed with humans for scarce resources. The absence of the domestic triad in the Marianas cannot be explained

by isolation following initial colonisation as there is ample evidence of external contacts with populations where domestic animals were present including the prehistoric introduction of rice from Asia (Hunter-Anderson *et al.* 1995) and regular contacts with Carolineans prior to the Spanish conquest in the 1700s (D'Arcy 2001).

This brings us back to the question of how we can model human colonisation and migration through zooarchaeological evidence. Apart from the conclusion that human transport of animals in Micronesia was both intentional and culturally situated, the existing evidence generates more questions than it answers. Why was pig restricted to only two locations in western Micronesia and apparently extirpated in one of them? Is the limited prehistoric presence of dog in western Micronesia compared with central-eastern Micronesia real as I suggest and if so, does it reflect differences in patterns of migration to the west and east of the Andesite Line? How do we explain the apparent presence of the three domestic animal species and the commensal Asian rat on the tiny island of Fais throughout the prehistoric sequence? Does this imply that Fais was an important interaction node straddling the boundary between western and central-eastern Micronesia? If so, will it be possible to identify the sources and timing of these introductions? Providing answers to these questions will shed considerable light on patterns of prehistoric mobility and commensal relationships between humans and their animal companions.

In conclusion, the uneven distribution patterns of prehistoric fauna brought into Micronesia and elsewhere in Remote Oceania reveal the complexity of human behaviour which can be informed by faunal evidence. The data presented are a caveat against overly simplistic assessments of the faunal record and support the need for more socially based models in archaeozoology which was the central theme of the ICAZ 2002 conference. While our understanding of the factors accounting for the presence and absence of introduced fauna on individual islands over time remains frustratingly limited, reviewing the general evidence provides insights into potential explanatory models which can be applied to specific data.

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Part II

Behavioural Variability in the So-Called Marginal Areas: a Zooarchaeological Approach

9th ICAZ Conference, Durham 2002
Colonisation, Migration, and Marginal Areas, (ed. M. Mondini, S. Muñoz & S. Wickler) pp. 42–45

6. Behavioural Variability in the So-Called Marginal Areas from a Zooarchaeological Perspective: aAn Introduction

Mariana Mondini and Sebastián Muñoz

This part of the volume corresponds to the session *Behavioural Variability in the So-Called Marginal Areas. A Zooarchaeological Approach*, held at the 9th Conference of the International Council of Archaeozoology (Durham, August 2002). This brief introduction aims at presenting the session theme as well as the papers included in this part of the volume, which represent varied, original contributions to the analysis of marginality from different perspectives.

Marginal areas have often been considered so not only geographically, but also in terms of their relevance for understanding our past. This assumption has been challenged, though, by regarding them as important as any other region for understanding hominid evolution and other aspects of our history, either in the remote past or in recent times (*e.g.* Gamble 1992, 1993; Coles and Mills 1998). It has now been acknowledged that marginality is definitely not an inherent property of certain areas or environments, but it is a relative quality. It is relative not only to the characteristics of these places and environments, but also to those of the species and populations involved. These, in turn, are not constant but vary with history.

In a recent review of the different conceptions of marginality in archaeology, Coles and Mills (1998) have stressed the fact that there are several overlapping definitions, and that no unique explanation is satisfactory. The point is, we would like to emphasise, that whichever definition is used it be explicit. They have recognised at least three definitions: an environmental one, an economic one, and a social/political one (Coles and Mills 1998).

Here we would like to draw attention to a further conception of marginality: a biogeographical one. From this perspective, 'marginal' areas would be those at the boundaries of the geographic range of humans and other hominid species. We believe that if we are to understand the whole range of hominid adaptations and the variation they encompass, the so-called marginal areas have a role to play. The behaviours involved in the outskirts of their geographic range can help understand such general issues as, for instance, the reasons and mechanisms of range expansion. One of the most relevant dimensions of such behavioural variability is that concerning hominid resource niches, which is approached here from a zooarchaeological perspective.

About a decade ago, Gifford-Gonzalez (1991) drew attention on the need that zooarchaeology move beyond agent identification towards wider, more general contextual inferences on hominid behaviour and ecology. As she put it, the new challenge of zooarchaeology at the time was precisely to aim at understanding those life relationships, as simpler models derived from lower organisational levels may not fully account for them. We believe that the study of marginality from a biogeographical standpoint may be a contribution in that direction.

Zooarchaeology is an appropriate field for such a study, as the zooarchaeological record is informative of the relationship of hominids to faunal resources, which comprises an important part of resource niche. Such relationship is variable not only in time but also throughout space, and the position of a given population within the species range is of much significance.

The margins of the geographic range

The outskirts of the geographic range are germane to the study of behavioural variability, since environmental conditions are not evenly favourable throughout the range of species, and the position of any given population within it is itself a source of variation (see Hengeveld 1990). For instance, it can be expected that some areas close to the margins of the range be 'sink habitats,' that is, ones that being in so marginal environmental conditions depend on receiving a sufficient supply of immigrants for

maintaining a local population, which may in turn affect several niche dimensions. On the other hand, areas out of the geographic range are not necessarily environmentally unfavourable for a given species, but they can just be separated by much distance or by unfavourable environments acting as barriers at a given moment in that species' history. Also, local extinctions are more likely to occur on the periphery of species ranges (Brown and Lomolino 1998; but see Sagarin and Gaines 2002). As a result of these properties of marginal areas, isolation can be common in them. Isolation is very relevant to behavioural variability, as it can promote variation, and in fact it is a key factor in allowing evolutionary change (Cox and Moore 1985).

There is a close relationship between a species' niche and its range, and the latter can be conceived as a spatial dimension of the former, although there are some other factors, like the ones mentioned above, affecting range boundaries (Brown *et al.* 1996; Brown and Lomolino 1998). In any case, geographic range margins tend to be unfavourable in some niche dimension/s, which helps shape range boundaries. Hence, attention should be focused on a somewhat different but closely related issue: behavioural variability at environmentally marginal areas – i.e. extreme altitude, extreme aridity, etc. Investigation of hominid adaptations to such conditions is not only an interesting issue itself, but it can also help understand many biogeographic aspects of our past history.

With expansion and colonisation cycles, not only the size and shape of the geographic range of species vary, but the range of exploited resources and habitats may change as well. As implied in this temporal aspect of marginality and in the stress in some niche dimension/s mentioned above, these processes are not only geographical but also ecological (Brown *et al.* 1996; Brown and Lomolino 1998), which is certainly worth exploring from a zooarchaeological perspective.

Variable margins

Marginality is relative to the properties of the areas and habitats and those of the species involved, as well as to history. Here we would like to illustrate this with some examples.

As to the first issue, range margins tend to be unfavourable in some way to the species in question, as mentioned above. There is however one important exception to this: coastlines (Brown and Lomolino 1998). In this case, geographic marginality does not necessarily imply other characteristics commonly attributed to these areas and the populations in them. This is relevant to the fact that one of the largest barriers that hominids have had to overcome in their range expansion is oceans. Navigation turned these barriers into spatial continuity.

This relates to the second issue: marginality in relation to the species involved. In the case of modern humans, some characteristics have resulted of utmost importance in geographic and ecological expansion, among them a flexible behaviour along with planning and organisational capacities (Gamble 1994; Foley 1995; Futuyma 1998). It is characteristics such as these that have allowed modern humans to occupy most environments on the biosphere, even those otherwise too difficult to live in, such as tropical rainforests (Politis and Gamble 1996), and to go beyond further biogeographical barriers than other hominids had, such as open oceans and high latitudes (Gamble 1994; Foley 1995; Fitzhugh and Hunt 1997; Brown and Lomolino 1998).

Precisely, marginality is also relative to history (*e.g.* Brown *et al.* 1996). History affects not only the areas and environments where the species we study set their ranges, but also these species and populations themselves. In the case of *Homo sapiens*, range expansion has not been gradual but episodic, which implies varying rhythms and rates of expansion (Gamble 1994; Foley 1995). As Gamble (1993, 1994) points out, we still do not know enough on the behaviours involved in such a massive range expansion. We believe that understanding variability on marginal areas can help explain it.

On how marginality is perceived

As a result of all these considerations, it must be emphasised that marginality is a dynamic concept, in the sense that any given area is not inherently marginal but it can be so at a given point of time relative to its own changing properties and those of the species in question. This is particularly so when the species considered is as flexible as are modern humans.

Besides, it should be taken into account that as range area increases with distance from the centre, range margins require greater sampling in order to account for the whole array of variation potentially implied (see Sagarin and Gaines 2002). Even in the case of cosmopolitan species as modern humans, sampling the peripheries of its distribution requires explicit, systematic strategies.

Finally, the point should be considered that not only actors perceive marginality differentially according to varying circumstances, but researchers ourselves also do so (Coles and Mills 1998; Cullen and Pretes 2000). Research agendas long disregarded the existence of a global colonisation prior to the recent one by European populations (Gamble 1992, 1993). As a consequence, marginality became a measure of the distance from the core European areas, and from 'progress.' As Gamble puts it, variability in past human behaviours must be considered if we are to build a further research agenda. We think that variability in biogeographically and ecologically marginal areas has a role to play in such an agenda.

Structure of this part of the volume

The contributions to the session have covered a range of issues regarding behavioural variability in marginal areas from a zooarchaeological standpoint. They describe a variety of instances from different parts of the globe, namely from Asia, Europe, Oceania, and North and South America. Apart from the papers presented here, the session also included one on desert adaptations in the Pre-Pottery Neolithic B in Jordan, by Rebecca M. Dean, one about contrasting subsistence regimes on remote oceanic islands, by Marshall I. Weisler, and a poster on the exploitation of small mammals, carnivores and reptiles in the arid margins of the Levant, by Liora K. Horwitz.

The papers in this part of the volume address the specifics and implications of human populations living in situations ranging from geographically peripheral areas to marginal environments. In the first group are Bar-Oz *et al.*´s and Borrero´s contributions. They deal with the occupation of the peripheries of the range of humans at a given time. The former refers to the southern Caucasus, a marginal area to the north of the human range during the Middle and Upper Palaeolithic, which would have served periodically as a refuge. The region would have been geographically marginal, but not environmentally so. The foraging behaviours of these populations are analysed in the paper, and are found to have a focus on prime-adult prey as well as a major component of specialised hunting of migratory herds, at least in the Middle Paleolithic.

Borrero´s paper is focused on Patagonia and, specifically, on the biogeographical 'dead ends' on the eastern fringe of the Continental Ice Cap. It discusses their marginal status relative to the geographic range of humans and to the home range of the groups inhabiting the region since the peopling of this part of the world. Support is provided to the latter role of these 'dead ends,' which would account for the patterns of faunal exploitation in these areas, such as the dominance of the same prey species as those away from the Andean Cordillera and of modern faunal resources generally.

Other contributions deal with the environmentally marginal conditions of areas that are geographically marginal as well, and with the implications of this for the economies of the groups inhabiting them. Such is the case of Darwent´s and Outram´s papers. The former focuses on the High Arctic of Canada and Greenland during the Paleoeskimo occupations. After the analysis of a wealth of zooarchaeological assemblages, Darwent concludes that climate fluctuations seem to account for inferred changes in faunal exploitation during most of this period. Towards the end of it, however, other factors would have become important, such as those related to competition with Neoeskimo groups.

Outram discusses the importance of bone fat in human diet, especially in marginal environments where dietary stress can be expected, within the frame of Optimal Foraging Theory. After outlining the methodologies for studying the archaeological signals of bone fat exploitation, the paper provides some examples from Greenland, Iceland, and Gotland. Evidence of dietary stress is found in some of the study cases, and the role of seasonality in this kind of stress is highlighted.

Another set of contributions deals with areas that are well within the human range boundaries of the time but represent environmentally marginal conditions. One of them, by Schmitt *et al.*, refers to a region where human populations experienced climate changes that promoted a harsher environment, while another one, by Arnold and Greenfield, discusses the change of an economic system and the concomitant incorporation of agriculturally marginal areas.

Schmitt *et al.* analyse changes in faunal exploitation during the middle Holocene desertification in Bonneville Basin, western North America. They find that with environmental deterioration, humans became more efficient foragers by mass collecting jackrabbits and increasing their mobility, and thus question the notion that harsh environments are necessarily marginal in terms of the affordances they provide to human adaptations.

Arnold and Greenfield analyse the timing of the origins of transhumant pastoralism in the northern Balkan Peninsula. They suggest a relationship between the advent of this economic strategy and the colonisation of the agriculturally marginal highlands of the region. While methodological issues hampered the faunal analyses, they suggest that the colonisation of the highlands would have begun at the end of the Neolithic and there are hints of transhumant pastoralism since the beginning of Post Neolithic.

Finally, Legge's discussion gives a full account of these varied approaches to marginality, along with his own views and experiences. His final conclusion captures the spirit of the whole session in its deepest meaning and suggests some of its most exciting implications.

In this brief introduction we have concentrated on the definition of marginality from a biogeographical standpoint and its connotations regarding behavioural variability. The varied, thought-provoking papers in the volume illustrate the contribution of zooarchaeological research to this area of enquiry, and provide an insight into a range of situations from which much can be learnt, showing that 'marginal' variability is as germane as any other for understanding our past.

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7. Faunal Exploitation Patterns along the Southern Slopes of the Caucasus during the Late Middle and Early Upper Palaeolithic

Guy Bar-Oz, Daniel S. Adler, Abesalom Vekua, Tengiz Meshveliani, Nicholoz Tushabramishvili, Anna Belfer-Cohen and Ofer Bar-Yosef

This paper provides preliminary results of our detailed taphonomic and zooarchaeological analysis of the faunal remains from the new excavations at the Middle Palaeolithic and Upper Palaeolithic sites of Ortvale Klde rockshelter and Dzudzuana Cave (1996–2001 seasons). We highlight the foraging behaviors and the depositional histories of the bone assemblages and draw broad conclusions regarding differences and similarities in hunting, butchering, and transport strategies of late Middle Palaeolithic and early Upper Palaeolithic occupants of the foothills of the southwestern Caucasus.

Introduction

Occupying an intermediate position between Africa, Europe, and Asia, the southern Caucasus has represented a northern geographic terminus for major expansions and migrations of human populations, both Archaic and Modern, for millennia. As such, the southern Caucasus provides an opportunity to examine human behavioral variability within a marginal area that periodically served as a refuge during the Palaeolithic. However, this stated marginality is only relevant in terms of geographic location, with human mobility being largely thwarted by the combined effects of the Caucasus Mountains to the north, the Black Sea to the west, and the Caspian Sea to the east. In addition, human mobility is limited to some extent by the Lesser Caucasus to the south. Within Western Georgia, the favorable climatic conditions produced and maintained by the Black Sea foster a degree of floral and faunal diversity that is not matched in these surrounding areas, thereby producing a highly productive yet circumscribed region capable of supporting large Palaeolithic populations. It is within this geographically marginal, yet environmentally diverse and resource rich region that we conducted excavations and zooarchaeological analyses as part of our investigation into the subsistence patterns and foraging behaviors of Middle and Upper Palaeolithic groups.

Western Georgia, located between the Caucasus range, the Likhi hills and the Black Sea, is a region known for its wealth of prehistoric sites, most of which are found in the river valleys that drain the Caucasus Mountains. Past research in this region established a cultural and palaeoenvironmental record (Liubin 1989; Adler and Tushabramishvili in press; Meshveliani *et al.* in press). Faunal studies were conducted solely as palaeontological investigations, resulting in presence/absence lists, without any zooarchaeological or taphonomic considerations. A recent Georgian-American-Israeli joint project centers on the excavations of two sites: Ortvale Klde rockshelter (Tushabramishvili *et al.* 1999; Adler 2002; Adler and Tushabramishvili in press) and Dzudzuana Cave (Meshveliani *et al.* 1999). This paper provides preliminary results of our ongoing detailed taphonomic and zooarchaeological analysis of the faunal remains recovered during these new excavations between 1996–2001.

The site of Ortvale Klde rockshelter is located in the Cherula river valley, approximately 5 km west of Dzudzuana Cave, which is located in the Nekressi river valley. Both are tributaries of the Kvirila River, which drains the slopes of the southwestern Caucasus (Figure 1). The two sites are located within the same ecological and geographical setting and provide a continuous cultural sequence. The sequence at Ortvale Klde is composed of five late Middle Palaeolithic layers (*c.* 60–33ka BP) that are capped by three Upper Palaeolithic

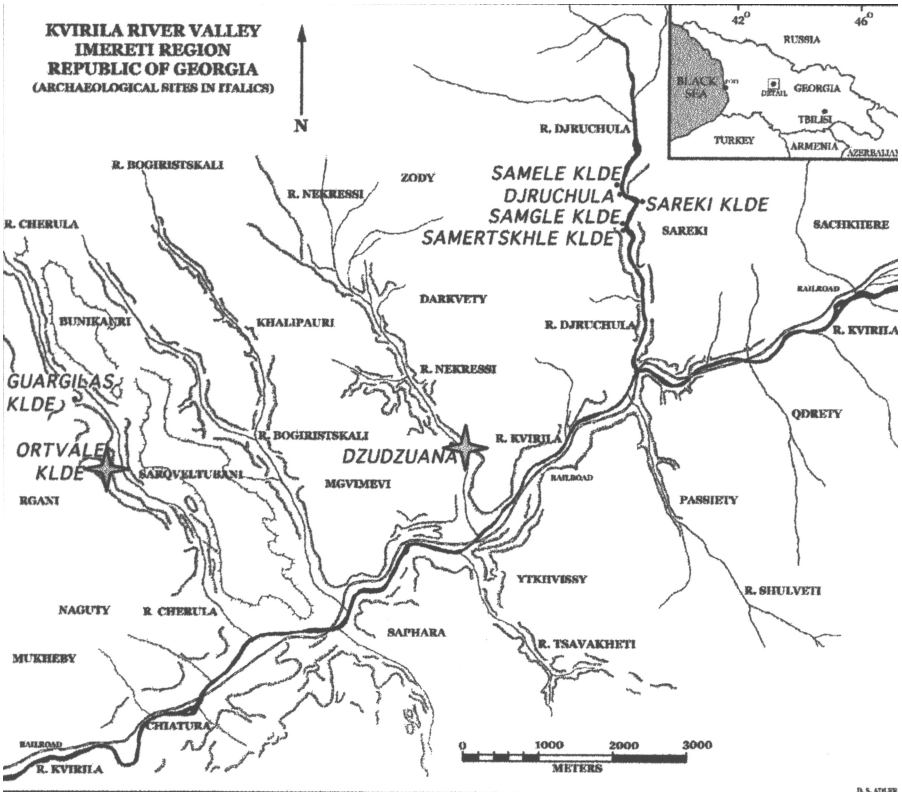

Fig. 1. Map showing the location of Ortvale Klde and Dzudzuana, Imereti Region, Republic of Georgia.

horizons (*c*. 33–21 ka BP). The sequence continues at Dzudzuana with two thick Upper Palaeolithic deposits dated to 30–20 ka BP and 13–11 ka BP. The lower deposit at Dzudzuana is contemporary with the Upper Palaeolithic horizons of Ortvale-Klde and the upper deposit resembles Epi-Gravettian manifestations in the region (see Adler and Tushabramishvili in press; Meshveliani *et al.* in press).

Ortvale Klde is situated at approximately 530 m above sea level, roughly 35 m above the gorge, and opens to the east. The new excavations were carried out in six square meters in the southern chamber of the rock-shelter (see Adler 2002; Adler and Tushabramishvili in press for site plan and area of recent excavation). Dzudzuana is situated in a similar environment (560 m above sea level, 12 m above the gorge). The cave is large and elongated, emerging as a tunnel from which a small creek flows. The new excavations were carried out in 16 square meters at the mouth of the cave (Meshveliani *et al.* 1999). All of the excavated sediments from both sites were sieved with 2 mm mesh (wet sieving at Dzudzuana and dry sieving at Ortvale Klde), and were processed according to their spatial and stratigraphic location.

We carried out detailed taphonomic and zooarchaeological analyses at both sites in order to gain a better understanding of the differences and similarities between the late Middle Palaeolithic and the Upper Palaeolithic foraging patterns in the region. Here we focus on the two most abundant species exploited during those periods – the Caucasian goat (*Capra caucasica*) and the extinct steppe bison (*Bison priscus*). These two species provided the economic base for the inhabitants of both sites over the entirety of their occupations. Our principal goal is to examine if and how Middle Palaeolithic populations (presumably Neanderthals) varied in their foraging behaviors and hunting strategies from Upper Palaeolithic populations. Another aim is to reconstruct the depositional history of each site and to document inter-assemblage differences in their formation processes.

Faunal analysis procedures

Bone fragments were identified in the field to the maximum number of skeletal elements including head fragments, vertebrae, ribs, and shaft fragments; specimens within this last category were identified to size class only. Taxonomic identifications were verified with the assistance of Professor A. Vekua from Georgian State Museum.

The relative abundance of each different taxa was quantified using NISP (number of identified specimens) and MNI (minimum number of individuals). These values were calculated using the assumptions described by Klein

and Cruz-Uribe (1984). Since the overwhelming majority of identified specimens were heavily fragmented, our protocol coded bones according to skeletal element, the portion of the element (*i.e.* proximal epiphysis, distal epiphysis, diaphysis, etc.), and what fragment of the bone portion is represented (*e.g.* lateral-medial, dorsal-ventral, caudal-cranial). In addition, each bone element was coded according to its degree of completeness (*i.e.* percent of preservation). When possible, shaft fragments were coded according to specific diagnostic zones. All identified elements were then summed to estimate the number of complete bones. In this method MNIs do not depend on the degree of fragmentation (Klein and Cruz-Uribe 1984).

The recorded elements were analyzed for butchery marks, and signs of animal activity (Fisher 1995). In addition, bone surfaces were analyzed for signs of post-depositional bone weathering (Behrensmeyer 1978), abrasion (Shipman and Rose 1988), and fluvial transport (Shipman 1981).

The mode of bone fragmentation was analyzed for all bone fragments bearing ancient fractures; fragments with recent fractures caused during excavation were not considered. The outline, edge, and angle of fractured specimens were assessed in order to determine the stage at which they were broken (*i.e.* fresh vs. dry; see Villa and Mahieu 1991 for typological description).

The distribution of various skeletal elements of Caucasian goat and steppe bison, grouped into four carcass part categories (head, trunk, limbs, and toes) was studied in order to determine which body parts were present at the site. The observed values for each body part were calculated based on MNE values, and the expected values were based on MNIs obtained for each species.

The age structure of the major hunted species (Caucasian goat and steppe bison) was analyzed on the basis of tooth wear. We followed Stiner (1994) in distinguishing three broad age classes (juvenile, prime adult, and old adult) using the eruption and tooth wear patterns of the deciduous lower fourth premolar (dP4) and lower third molar (M3).

The bone assemblages of Ortvale Klde and Dzudzuana

Thus far, a total of 2,538 complete and fragmentary bones from Ortvale Klde (MNI=40) and of 1,628 complete and fragmentary bones from Dzudzuana (MNI=28) were identified to species, including elements that were identified only to body size group. The relative frequencies of the main hunted species in each of the assemblages are detailed in Figure 2 (based on NISP). Caucasian goat is the single most common taxon in each of the late Middle and early Upper Palaeolithic layers at Ortvale Klde. Within the Upper Palaeolithic layers of Dzudzuana the proportion of Caucasian goat decreases in favor of steppe bison. It is possible that the taxonomic differences observed between Ortvale Klde and Dzudzuana are reflective of differences in land use, but this theory remains to be tested. At each site these two species constitute more than 90% of the total assemblage (based on NISP). Other prey and non-prey species are represented at each site in small proportions, including aurochs (*Bos primigenius*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), equid (possibly *Equus caballus*), fox (*Vulpes vulpes*), and bear (possibly *Ursus spaleaus*).

The abundance of Caucasian goat at Ortvale Klde is remarkable, representing the only documented Middle Palaeolithic site in the Caucasus dominated by this species. The predominance of mountain goat in Middle Palaeolithic contexts has been also observed at Teshik-Tash in Uzbekistan (*Capra sibirica*: >80%; Gromova 1949), at the Spanish sites of Zafarraya and Acklor (Altuna 1989; Straus 1986, 1992; Barrozo-Ruiz and Hublin 1994) and at Hortus and Crousade in southern France (*Capra ibex*; Delumley 1972; Gerber 1972). Barakaevskaïa Cave, located roughly 350 km northwest of Ortvale Klde in Gubs Canyon (Northern Caucasus), contains a faunal assemblage with one of the highest percentages of Caucasian goat (28.2%; Liubin 1998). By and large, though, the Caucasian goat is poorly represented at Middle Palaeolithic sites in the Caucasus (Hoffecker *et al.* 1991; Baryshnikov and Hoffecker 1994; Baryshnikov *et al.* 1996).

Caucasian goat lives along steep rocky slopes at elevations between 800–2400 m and it follows a dramatic seasonal migration that can cover a vertical distance of more than 1500 m. In the early spring they climb high into the mountains, descending into the upper part of the boreal forest in the late fall (Vereshchagin 1967; Heptner *et al.* 1989). Similar seasonal vertical migrations, although less distinct, were followed by recent populations of steppe bison in the southern Caucasus (Vereshchagin 1967; Heptner *et al.* 1989). Thus, on the basis of these observations, the high proportions of Caucasian goat and steppe bison within each of the assemblages may reflect hunting activities that occurred during the late fall or winter.

The age distribution of Caucasian goats from the Middle Palaeolithic layers of Ortvale Klde and of steppe bison from the Upper Palaeolithic layers of Dzudzuana cluster into three main age categories, indicating a hunting preference for prime-age adults (Figure 3). The small sample size of steppe bison from Ortvale Klde and Caucasian goat from Dzudzuana did not permit a similar analysis. The mortality pattern clearly shows that both goat and bison culling fall within the 'ambush predator' portion of the triangular diagram, near the median values obtained by Stiner (1994) for the Middle Palaeolithic and late Upper Palaeolithic of Italy and the prey age classes obtained by Speth and Tchernov (1998) for the Middle Palaeolithic layers of Kebara Cave, Israel. Prime-age dominated assemblages are also reported by

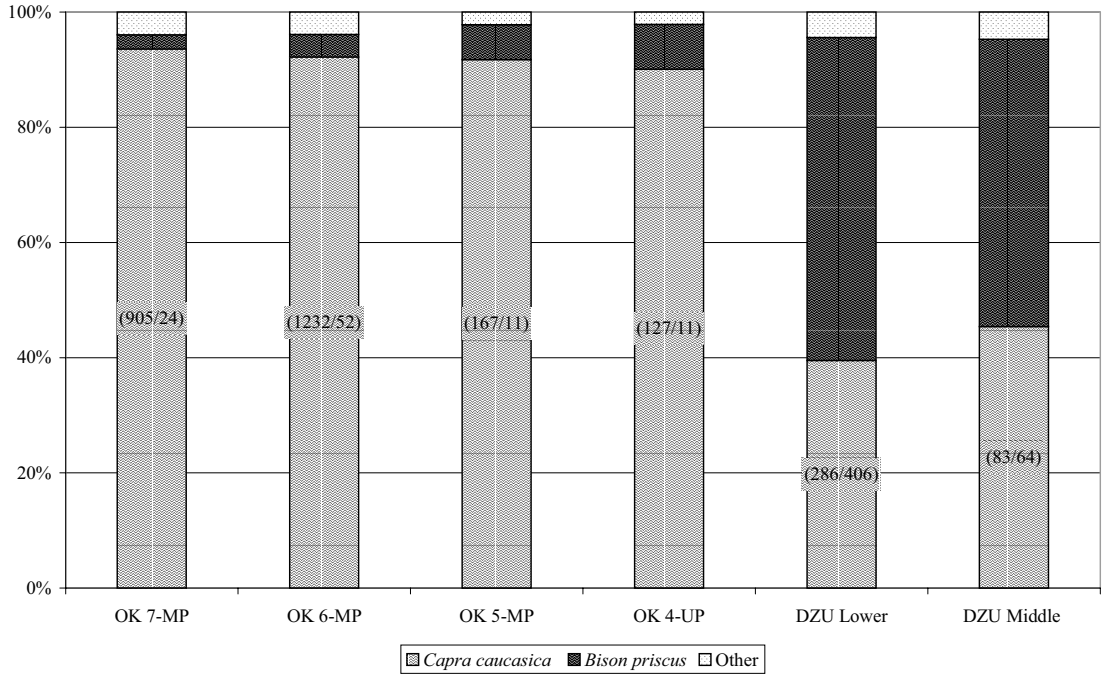

Fig. 2. Relative frequencies of the main hunted species from the Middle Palaeolithic levels of Ortvale Klde (Layers 7–5) and the Upper Palaeolithic levels of Ortvale Klde (Layer 4) and Dzudzuana (lower and middle layers). Other species include mainly aurochs, red deer, fox, and bear (NISP's in parentheses are given for each level for Caucasian goat and bison, respectively).

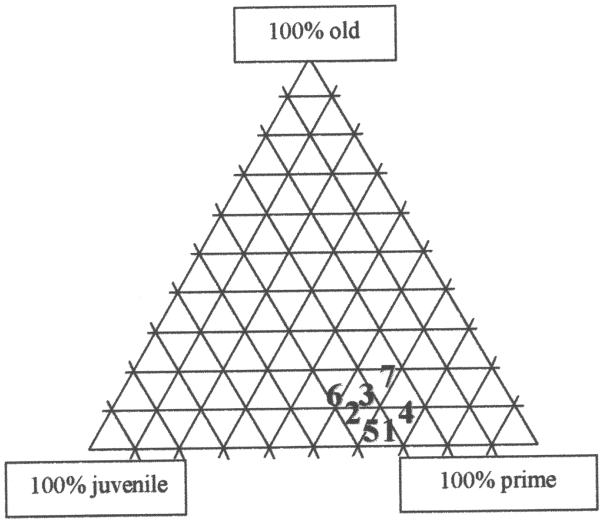

*Fig. 3. Mortality patterns of Caucasian goat in the Middle Palaeolithic levels of Ortvale Klde (1) and steppe bison in Dzudzuana (2) in comparison to the median values obtained by Stiner (1994) for the Middle Palaeolithic (3) and the late Upper Palaeolithic (4) sites from Italy, and in comparison to mortality patterns of gazelle (*Gazella gazella*) (5), fallow deer (*Dama mesopotamica*) (6), and red deer (7) in the combined Middle Palaeolithic of Kebara Cave, Israel (Speth and Tchernov 1998) .*

Gaudzinski (1995) for Middle Palaeolithic bison kill sites from Europe.

The taphonomic history of Ortvale Klde and Dzudzuana

The taphonomic history of Ortvale Klde and Dzudzuana reveal that different depositional processes shaped each of the assemblages. While the faunal remains from Ortvale Klde span the full range of bone densities, including porous parts such as the central portion of the atlas (0.07 g/cc; Lyman 1994; based on *Ovis aries* bone densities) and the caudal ischium (0.11 g/cc), the Dzudzuana assemblage is dominated by very dense bones, and contains mainly shaft fragments (over 0.4 g/cc) and teeth. This observation suggests differential rates of bone preservation at Dzudzuana owing to attritional processes that could have occurred during or following occupation.

Analysis of the breakage patterns on long bone epiphyses and near-epiphyses shaft fragments provided results that varied considerably between four layers of Ortvale Klde and the two layers of Dzudzuana (Figure 4). High proportions of dry bone fractures (*i.e.* right angle, transverse outline, and smooth edge) characterize Dzudzuana, while high proportions of fresh bone fractures (*i.e.* oblique angle, V-shaped outline, and jagged edge)

		Fracture angle			Fracture outline			Fracture edge		
Site	Layer	Oblique (fresh)	Right (dry)	Intermediate	V shaped (fresh)	Transverse (dry)	Intermediate	Jagged (fresh)	Smoothed (dry)	Intermediate
Ortvale Klde	7 (MP)	76 (74%)	12 (12%)	15 (14%)	17 (70%)	11 (11%)	19 (19%)	70 (70%)	7 (7%)	23 (23%)
	6 (MP)	153 (74%)	18 (9%)	36 (17%)	135 (64%)	19 (9%)	58 (27%)	153 (72%)	25 (12%)	34 (16%)
	5 (MP)	12 (80%)	1 (7%)	2 (13%)	11 (74%)	2 (13%)	2 (13%)	13 (87%)	0 (0%)	2 (13%)
	4 (UP)	23 (88%)	2 (8%)	1 (4%)	22 (84%)	2 (8%)	2 (8%)	24 (92%)	1 (4%)	1 (4%)
Dzudzuana	Early (UP)	57 (48%)	53 (45%)	8 (7%)	51 (44%)	48 (41%)	18 (15%)	54 (47%)	48 (41%)	14 (12%)
	Middle (UP)	75 (57%)	35 (26%)	22 (17%)	62 (47%)	27 (20%)	43 (33%)	44 (33%)	46 (35%)	42 (31%)

Fig. 4. Relative frequencies of fracture angle, fracture outline, and fracture edge from Ortvale Klde (Layers 7–4) and Dzudzuana (lower and middle layers).

characterize Ortvale Klde. A tree diagram designed to measure the degree of similarity in fresh bone fracture ratios from the different levels at the two sites places the Dzudzuana assemblage distinctively apart from the four layers of Ortvale Klde (Figure 5). These results suggest that the fracturing of bone at Dzudzuana most probably resulted from trampling, weathering, and/or sediment compaction, while the bones from Ortvale Klde were fractured in a fresh condition.

Results of the taphonomic analyses reveal that the high frequency of dry bone fractures found at Dzudzuana can be related to post-depositional physical erosion processes as evidenced by the high rates of abraded bones and the relatively wide distribution of bleached and eroded bones. In addition, the Dzudzuana bone assemblage bears evidence of advanced stages of bone weathering (stages 3–5 based on Behrensmeyer 1978). Figure 6 summarizes the results of each of the attritional processes considered. These results suggest that skeletal elements at Dzudzuana were probably exposed to more aerial weathering and were buried in less favorable sedimentological conditions in comparison to the bone assemblages from all levels of Ortvale Klde. The adequate representation (Voorhies Group I-III; Voorhies 1969) of bone elements according to their surface-volume ratio at both Dzudzuana and Ortvale Klde, suggests that the loss of bones owing to fluvial transport was minimal.

In addition, chewing, gnawing, and scratch marks (see Fisher 1995) are infrequent on all identified and unidentified elements from both assemblages (Figure 6), suggesting that the destruction of bone elements by carnivores and rodents was insignificant. It is possible that the absence of carnivore modifications in the Dzudzuana assemblage relates to the poor preservation of the bone surfaces. The presence of two carnivore marks on the inner parts of an occipital fragment of Caucasian goat from Ortvale Klde further supports the claim that carnivore activity at the site is associated with post-depositional processes.

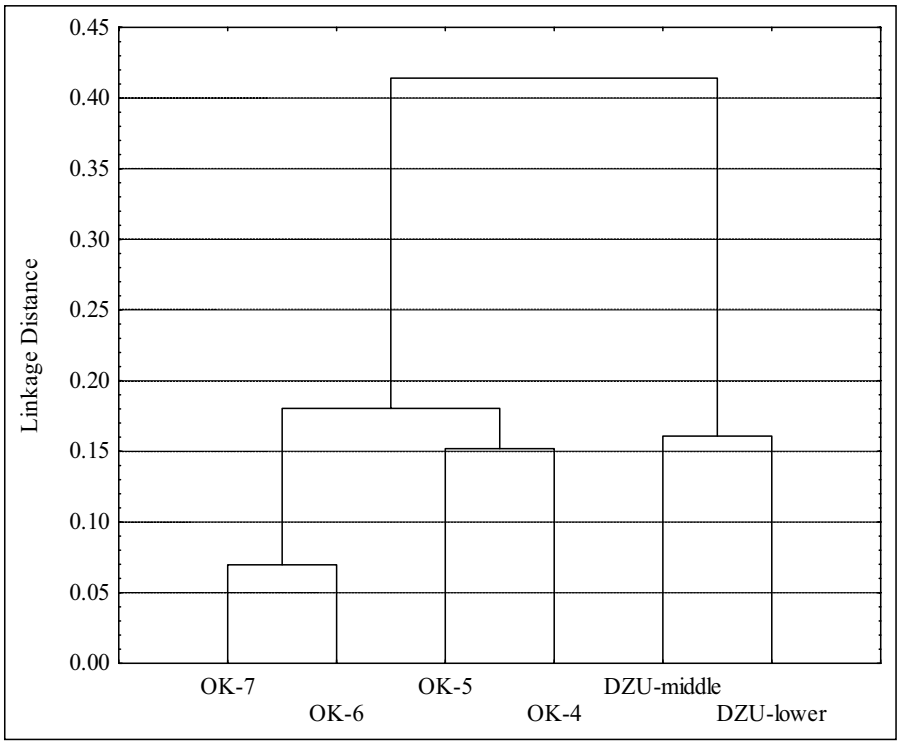

Fig. 5. Tree diagram (based on cluster analysis) measuring the similarity of fresh bone fractures from Ortvale Klde (Layers 7–4) and Dzudzuana (lower and middle layers), based on proportional frequency of fracture angle, outline and edge.

Site	Layer	% Abraded	% Bleached	% Weathered (>stage 2)	Fluvial transport	% Carnivore marks	% Rodent marks
Ortvale Klde	7 (MP)	0	0	5	Not significant	5	3
	6 (MP)	0	0	0	Not significant	7	3
	5 (MP)	0	0	0	Not significant	7	2
	4 (UP)	0	0	8	Not significant	8	2
Dzudzuana	Lower (UP)	12	2	35	Not significant	1	1
	Middle (UP)	20	9	76	Not significant	4	3

Fig. 6. Measured values (%NISP) of specific attritional processes from Ortvale Klde (Layers 7–4) and Dzudzuana (lower and middle layers).

Food transport and processing at Ortvale Klde and Dzudzuana

The Caucasian goat remains from Ortvale Klde exhibit marks from all stages of preparation (n=42); only three cut marks were found on unidentified shaft fragments of bison from the site. The majority of the butchery marks on the goat remains can be associated with carcass dismemberment (71%; following Binford 1981). Butchery marks indicative of skinning (5%) and filleting (24%) were also observed. Cut marks produced during dismemberment are often deeper and more pronounced than those produced during filleting, and are more abundant than skinning cut marks that are scattered, almost exclusively, along distal metapodia and horn cores (Noe-Nygaard 1989). The Dzudzuana assemblage contains a small number of cut marks on the goat (n=9) and bison remains (n=11), an observation that is most likely linked to the poor preservation of bone surfaces.

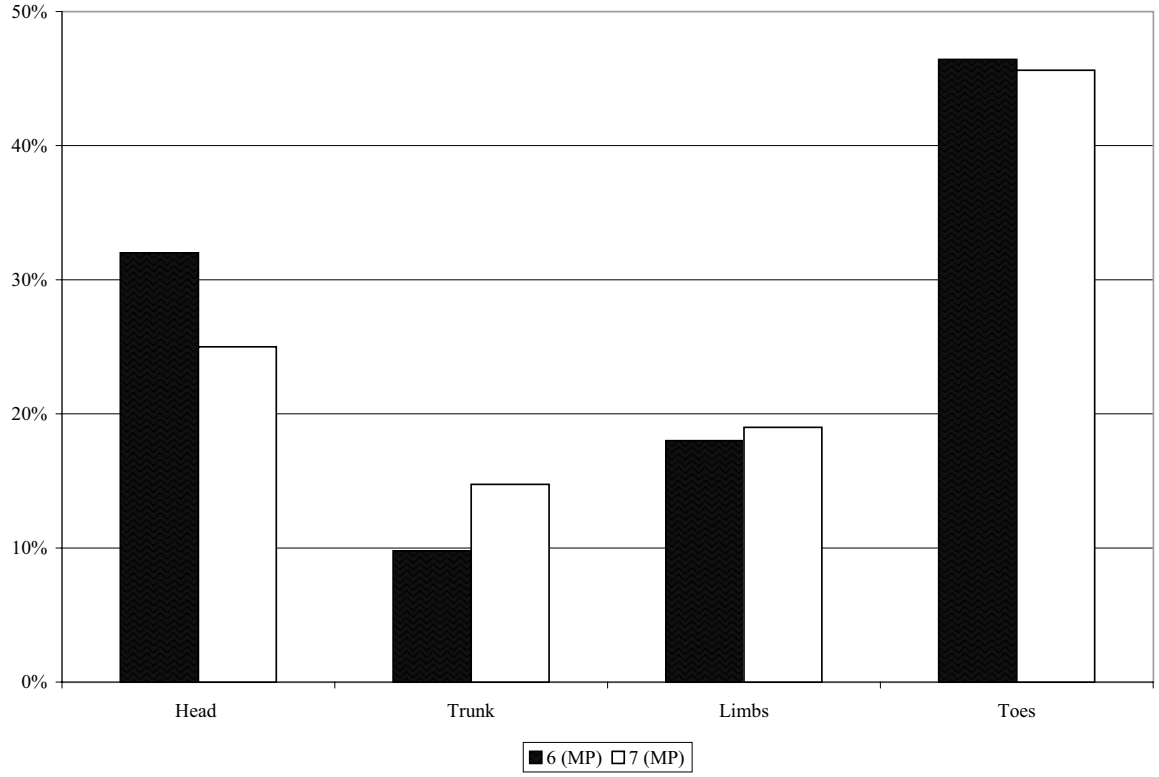

Fig. 7. Body part representation of Caucasian goat from the Middle Palaeolithic layers of Ortvale Klde (Layers 7–6) pooled into four carcass part categories.

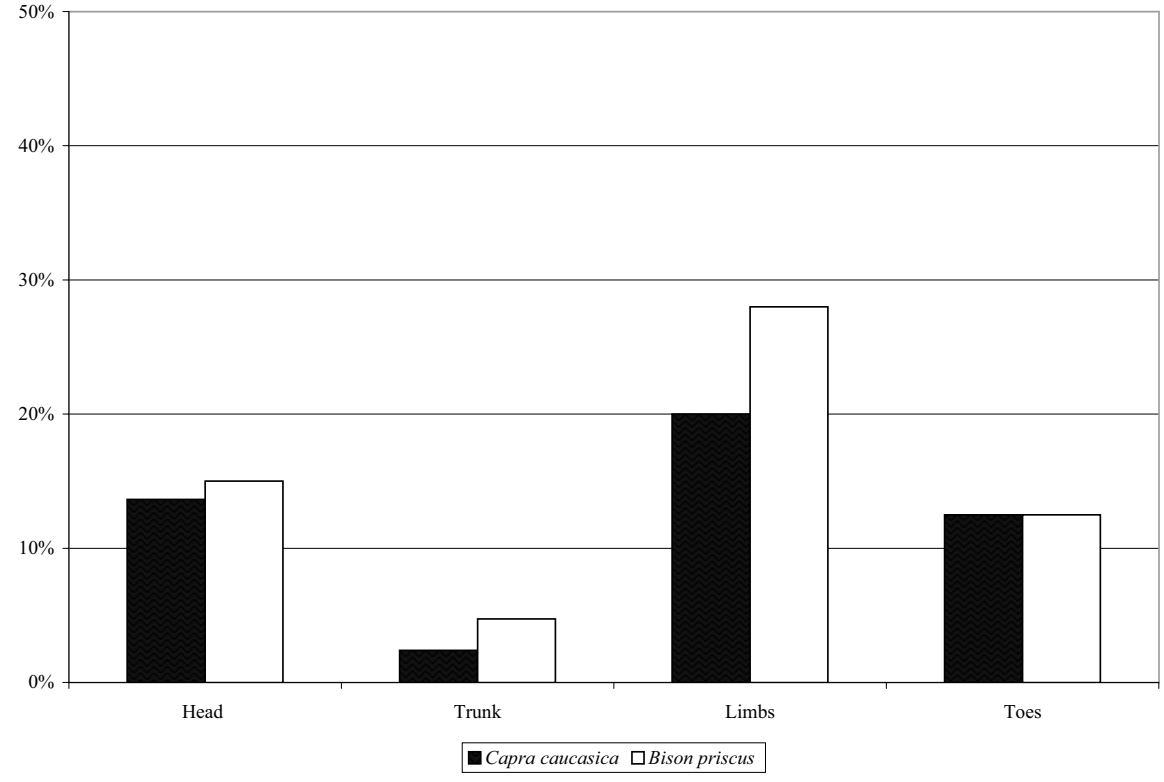

Fig. 8. Body part representation of Caucasian goat and steppe bison from Dzudzuana (lower and middle layers combined) pooled into four carcass part categories.

The distribution of Caucasian goat skeletal elements within the two main Middle Palaeolithic layers of Ortvale Klde (Layers 6 and 7), grouped into four carcass part categories (Figure 7; Bar-Oz n.d.), reveals a different representation pattern from that expected. The observed values are based on MNE and the expected values were calculated based on MNI. The ratio of the observed to the expected shows a low representation of trunk and limb elements, a moderate representation of heads, and a high representation of toes. An under-representation of vertebrae is common in many zooarchaeological assemblages (*e.g.* Brain 1981; Stiner 1994) and may result from various cooking and processing techniques. Likewise, the transportation of intensively processed carcasses to a site can also decrease the likelihood of encountering vertebrae within an assemblage. In addition, we found a relatively high proportion of scapulae and pelves, suggesting that certain axial elements were present at Ortvale Klde. The high frequency of toes in comparison to limb elements observed for class 2 bovids (*i.e.* those species equivalent in size to Caucasian goat) at Hadza base camps has been attributed to the butchery of the carcasses at the kill site and the transport of filleted meat from the heavier limb bones within the skins to which the phalanges remain attached (Monahan 1998).

It could be that the low rate of limb bones, in comparison to head parts, may be related to the season of the site occupation. Ethno-zoological observations demonstrate a preference for crania and toes during lean seasons, when the amount of fat and the quality of the meat in the limbs decreases (Speth 1987, 1989; Lupo 1998). Thus, the skeletal parts profile found at Ortvale Klde may reflect hunting activities that occurred during the winter, when the physical condition, and therefore nutritional potential of Caucasian goats had begun to decline. The skeletal part distribution for both steppe bison and Caucasian goat from Dzudzuana, apart from the problematic counts of the vertebral elements, display profiles that approximate anatomical completeness (Figure 8; Bar-Oz n.d.).

Concluding remarks

In this study we have attempted to highlight the foraging behaviors and the depositional histories represented at Ortvale Klde and Dzudzuana. These preliminary results enable to draw several broad conclusions regarding hunting, butchering, and transport strategies during the late Middle Palaeolithic and the early Upper Palaeolithic of the southwestern Caucasus.

- The scant evidence for carnivore activity may imply that human occupations at Ortvale Klde were frequent and lasted for prolonged periods of time.
- The presence of cut marks relating to all stages of processing among the remains of Caucasian goat from Ortvale Klde suggests that some degree of on-site butchering was carried out.
- The dominance of Caucasian goat at Ortvale Klde suggests that the specialized hunting of predictable, migratory herds, was a major component of Late Middle Palaeolithic food-management strategies in the foothills of the southwestern Caucasus. The abundance of goat remains at both sites and the skeletal parts profile of goat at Ortvale Klde, coupled with the abundance of bison at Dzudzuana may indicate that hunting activities were conducted during late fall or winter.
- The analysis of prey age classes of Caucasian goat and bison demonstrates that the Late Middle Palaeolithic inhabitants of Ortvale Klde and the Upper Palaeolithic inhabitants of Dzudzuana were capable hunters who preferentially targeted prime adult prey.

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8. The Archaeozoology of the Andean 'Dead Ends' in Patagonia: Living near the Continental Ice Cap

Luis Alberto Borrero

*The Continental Ice Cap, an impressive accumulation of ice, extends more or less continuously between 46º and 51º 30′ S in Southern Patagonia. Many proglacial lakes, separated by notches of moderately high terrain are located East of the Ice Cap. These zones constitute biogeographic "dead ends", limited by the Cordillera and the lakes. The Ice Cap was the Western limit for the expansion of human populations and other species for the last 12,000 years. It is known that Patagonia was peopled near the end of the Pleistocene, a time at which this formidable barrier was even higher. The archaeological record suggests that the initial human installation took place at the Eastern steppes, and that only during the early Holocene the exploration of the "dead ends" began. The occupations near the Ice Cap are always characterized by the exploitation of modern faunas, especially guanaco (*Lama guanicoe*). Thus, the faunal assemblages do not differ significantly from those recorded away from the Cordillera. This pattern may be related with the existence of a less attractive and marginal environment near the Cordillera. It was marginal because it was discontinuously used in relation with the main human circulation corridors in Patagonia. In sum, the chronologies, the rate of deposition of faunal remains and the species represented suggest that the assemblages recovered near the Cordillera are the result of the discontinuous utilization of the "dead ends" located between proglacial lakes, a pattern probably related with the progressive exploration and colonization of marginal zones.*

Introduction

Marginality is a culturally charged concept. It is not connected with 'second class', or any similar deprecatory meaning, but with spatial position. For example, it can be asked if marginality implies a harsher or more costly environment, and the answer is 'Not necessarily'. Marginality is the result of the distribution and functioning of populations.

I have selected a biogeographical approach that takes into account the spatial distribution of populations, and tries to make sense of them (Morain 1984). There are several ways to define and conceptualize 'marginality'. I do not intend to review all the different meanings attached to this term. I will only deal here with some uses that possess clear material implications. One way to conceptualize marginality is based upon the relictual distribution of a species. For example, the distribution of horses comparing 'their mid-Tertiary abundance to modern marginality in both place and number' (Gould 2002, 905 and 907). One particularly good example – and closer to our subject – is given by the relictual distribution of *Neandertal* populations and/or Mousterian assemblages South of the Ebro (Straus 2001), in Southern Italy (Kuhn and Bietti 2000) or in Eastern Europe (Smith *et al.* 1999) after 40,000 BP. Under conditions of turnover by *Homo sapiens*, *Neandertal* groups were clearly restricted to peripheral portions of their original distribution.

Then, we can suggest that remnants of populations, concentrated in a limited part of their original range, or in a more or less isolated part of the actual range, are marginal. These places need not be resource poor, as the case exposed for the *Neandertal* makes abundantly clear, and are usually conceptualized as 'refuges'.

Geographical marginality may be associated with reproductive isolation or not. It is crucial to evaluate if discrete biologically viable groups can be identified or not. These are, respectively, the successful and unsuccessful ways to be 'marginal'. The former may produce to peripatric speciation or, in general, divergence. If peripheric groups do not constitute discrete units, then metapopulational theory that refers to fragmented populations that remain barely connected through corridors is

relevant. Biological viability at each *locus* is dependent on these connections, and any difficulty in the circulation implies the potential extirpation of demes.

Another case of geographical marginality implicates land that is discontinuously occupied or exploited from distant population cores. In this case the lands, which are included within the home range of the groups, are defined as marginal on the basis of their infrequent use.

For a marginal condition to exist, then, there are at least two cases: (1) a discrete deme whose connections with the main population are severed or tenuous, and (2) discontinuous use of a piece of land from a distant population core.

Patagonian 'Dead Ends'

There are several scales at which marginality can be defined. The first volume of the *Handbook of South American Indians* – '*The Marginal Tribes*'– (Steward 1946) was conceived under the marginality concept, and implies the land as well as the people inhabiting the land. Marginality in these cases applies at a continental, or hemi-continental scale. Earl Saxon, in his celebrated paper on the colonization of Fuego-Patagonia, considered that this area itself was marginal (Saxon 1976). Moreover, it is possible to define marginality at a regional scale. Some of these cases, the marginal lands and people within the Patagonian landscape, are going to be the subject of this chapter.

It is a truism of biogeographical analysis that there is always inhomogeneous occupation of space. In the particular case of Patagonia there are many reasons behind this space hierarchy. One of the most important reasons is, of course, that – starting with order of arrival – there was order in the initial peopling of Patagonia. The probably slow process of infilling the land, given the human dependence on the availability of land and other resources, must have been uneven, producing a patchy distribution. It is known that Patagonia was populated near the end of the Pleistocene, a time at which a formidable barrier – the Continental Ice Cap, a remnant of the last glaciation – was separating the Patagonian steppe from a belt of discontinuous forested lands on the Pacific Ocean to the West. This Ice Cap extended South of 46º S, and is composed of 'the two largest icefields in the Southern Hemisphere outside Antarctica' (Rabassa and Clapperton 1990, 155). The North Patagonian Icefield is 4,200 square kilometers. The South Patagonian Icefield, located between 48º 20´ and 51º 30´ S, is 13,000 square kilometers (Casassa *et al.* 2000) (Fig. 1). These icefields are between 600 and 1,000 meters thick. This barrier is responsible for the asymmetrical pattern of human distribution, with most of the archaeological evidence concentrated in the Eastern side of the Cordillera (Borrero and Franco 1997).

On a finer scale, large outlet glaciers formed many proglacial lakes, most of which are connected with the Atlantic Ocean. These lakes are separated by zones of moderately high terrain, with a belt of *Nothofagus* forests parallel to the Cordillera. These zones are biogeographic 'dead ends', limited by the Cordillera and the lakes.

All the evidence points out that the initial peopling in the Late Pleistocene probably was a process that initially took place near the coast (Borrero 2002). The archaeological record suggests an early Holocene exploration of the near-Cordillera habitats, which – as was already said – usually are blind alleys. As it will be seen here, it can also be defended that in many cases these lands were marginally used from centers located in the steppe.

In the first place it must be pointed out that we have abundant evidence for the coexistence of humans and megafauna in sites away from the Cordillera (Menghin 1952; Bird 1988; Miotti 1996). In order to sustain my argument of human marginal use of the habitats located near the Cordillera, I will try to provide evidence for: (1) an order of succession in which megafauna was using the area before the arrival of humans, which occurred after the extinction, in sites near the Cordillera, and (2) the existence near the Cordillera of very limited evidence of the use of specific resources, different from those exploited in the steppes.

The evidence

I will introduce and shortly discuss the evidence from some of the regions near the Cordillera for which we have archaeological information.

1) Ibañez River basin: The Ibañez River, in Chile (*c.* 46º S, 300 masl), limits at its headwaters with dense stands of forest and the Ice Cap (Mena 1999, 58). Human installation occurs late in the Holocene, a fact that can be related with its difficult access (Reyes 2002). To explain the presence of humans in this basin a model of peopling of the area from the Eastern steppe was presented (Aschero 1996; Mena and Jackson 1991). This region is located North of the long lake General Carreras-Buenos Aires, which posed a constraint on human circulation.

   The archaeological record shows discontinuities. It is important to note that human occupation is discontinuous in the short term – meaning short stays– and also in the long term – with a long hiatus of thousands of years. This is a characteristic that may be related with the marginal situation of the Ibañez. Also, the manifestations of rock art, which is similar to that of the East, but less abundant in comparison with Río Pinturas or Cerro de los Indios (Lucero and Mena 2001), appears as marginal. Lucero and Mena found formal similarity, which they think is suggestive of pene-contemporaneity with the rock art of the Río Pinturas area. Moreover, obsidian found at the Ibañez was collected at Pampa

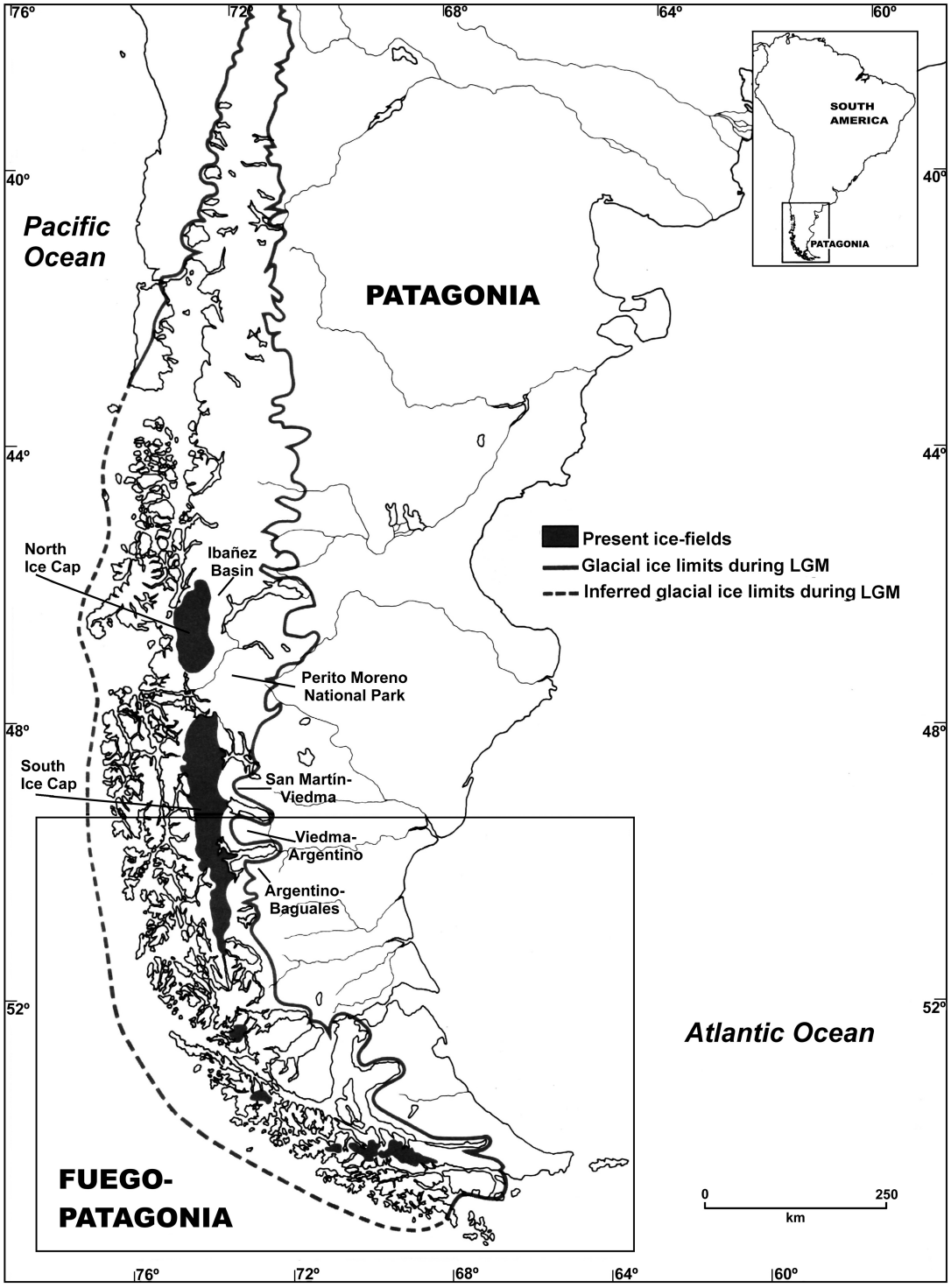

Fig. 1. Location of present ice fields and "dead ends" in Patagonia. Transformed from McCulloch et al. *(1997, 21).*

del Asador – a source located in the Eastern steppe – (Stern 1999; Espinosa and Goñi 1999). Exloitation of the huemul (*Hippocamelus bisulcus*) is indicated in the faunal assemblages of the Ibañez sites. No evidence for the presence of megafauna was found. All this information is convergent in an interpretation of occupations resulting from discontinuous activities.

2) Parque Nacional Perito Moreno (46º 30′– 48º S, *c.* 800 masl). This Park was presented as a 'dead end', in which the San Lorenzo Mount is the Western limit (Espinosa 2002; Aschero *et al.* 1992, 1992–

1993). Access to this Park probably occurred through the Aguila Plateau and the Belgrano River Basin. A paleolake was possibly present, constraining circulation. The Pampa del Asador obsidian source is located along this circulation corridor. Alternatively, a route through the Alto Río Pinturas, Lake Posadas and Río Belgrano was suggested (Aschero 1996, 19).

The archaeology of the Park is well known. Specific information from several sites can be used to assess the case for marginality, especially Cerro Casa de Piedra 7 (CCP7) (47° 55′ S), which is located at approximately 900 masl, in the current forest-steppe ecotone. CCP7 is about 25 km East of the Cordillera and 5–6 km from the Burmeister Lake. It was occupied by humans between 9,700 and 3,400 BP. Importantly, there are no evidences of coexistence of humans and megafauna at the site, even when megafauna dung found below the initial human occupation was dated *c.* 10,500 BP (Aschero and Civalero 1998). Faunal analysis shows the presence of huemul and guanaco (*Lama guanicoe*) bones (De Nigris 2001). The initial occupations are interrupted and discontinuous. The evidence from another site, Cerro Casa de Piedra 5 (CCP5), indicates initial utilization by mid-Holocene times. The presence of huemul remains is also recorded (Aschero 1981–1982). In general, the pulses of human utilization become more intense in the latter part of the Holocene (Aschero *et al.* 1992, 97).

Chronological evidence suggests that the use of the area was discontinuous in time (Goñi 1988). Lithic raw materials used to construct artifacts are all imported, especially black obsidian that was obtained some 40 km to the East, in the steppe. It was postulated that this area was colonized from a population core located in the Río Pinturas area (Aschero *et al.* 1992, 98; Aschero 1996, 19). Espinosa's analysis of lithics is in agreement with this interpretation. She found that logistic use of the near-Cordillera forest is the most economic way to explain the lithic distribution patterns (Espinosa 2002). Especially important is her observation of decreased diversity of classes of lithic artifacts in the forest. She maintains that: (1) the forests were logistically exploited from the steppe, (2) that human groups were moving into the forests with a basic and specific tool kit, and (3) that they were intensively using the Pampa del Asador obsidian source (Espinosa 2001).

The study of the lithic materials at the Alero Destacamento Guardaparques site (ADG) – a limited activities location- helps to remark that the use of obsidian is more important than that recorded at the Río Pinturas sites (Cassiodoro *et al.* 2001), even when they are more or less at the same distance. I believe that it is the location of ADG, West of the obsidian source, that explains this situation. Also, the faunal analysis of the guanaco remains obtained at ADG supports the notion of logistical exploitation from the East (Rindel 2003).

Then, it is clear that the Holocene use of the Parque Nacional Perito Moreno sites can best be explained from the East (Aschero *et al.* 1992–1993, 149). The lithic evidence, the short-term pattern of occupations, as well as the limited role of the huemul can be used to defend a model of marginal utilization.

3) Lago Argentino-Baguales: The 'dead end' defined by Lago Argentino in the North and Baguales Range in the South, with the Ice Cap in the West, is characterized by the presence of a complex lake system that constrains circulation (Borrero and Muñoz 1999). Different studies in geology and palynology inform that the area was free of ice at least since *c.* 10,000 BP (Mancini 2002), and thus available for human use.

   The Chorrillo Malo 2 site is located at 200 masl, about 25 km from the Cordillera. It was intermittently occupied since *c.* 9,700 BP, and guanaco remains are dominant throughout the sequence. An analysis of the temporal distribution of archaeological radiocarbon dates from several sites around the Lago Argentino suggested that the use of the area was interrupted during the Medieval Warm Anomaly, a time at which the main problem probably was for circulation across the mesetas (Borrero and Franco 2001). This may also be indicative of an area which was exploited from far away centers, and that began to be discontinuously used when there was a change in the availability of water. An exhaustive analysis by Nora Franco of the distribution of artifacts made on raw materials with known provenience also suggests that this area was discontinuously used from population cores located in the steppe (Franco 2002).

Other cases

There are other 'dead ends' in Southern Patagonia, but most of them simply lack the kind of research that is necessary to discuss the issue. Among them it is important to mention at least two cases. In the first place the case of the Lake San Martín-Lake Viedma. Only a limited amount of research was conducted in this area, basically on the Northern shore of Lake Viedma (Caracotche 2001; Caracotche and Belardi 2001). At the site Punta del Lago there is an important concentration of wall paintings and engravings (Menghin 1952). Sites with obsidian from Pampa del Asador are known for this area (Molinari and Espinosa 1999). No chronological framework is available.

Finally, the case of the 'Peninsula' between Lakes Viedma and Argentino must be mentioned. This area is characterized by a low rate of sedimentation. All the limited archaeological evidence suggests a very late and intermittent occupation of that space (Belardi and Borrero

1999). An analysis of the design properties of instruments recovered in the 'Peninsula' suggested that a model of land use and exploitation centered in the East (see Franco 2002) best explains their presence.

Finally, a comment must be made about other sites located well North of the Ice Caps. In at least three sites there are paleontological layers with megamammal remains – ground sloth (*Mylodon darwini*) – without human association, and archaeological layers immediately above. The sites are Baño Nuevo (Mena and Reyes 1998), Traful (Crivelli *et al.* 1993) and El Trébol (Hajduk *et al.* 2002). At Cuyín Manzano (Cevallos 1982) and Epullán (Crivelli *et al.* 1996), the early Holocene human occupations are associated with modern faunas. All this evidence suggests that the earliest human occupation in North Patagonia is posterior to the disappearance of megamammals. These evidences suggest that the patterns discussed near the Ice Cap need not be exclusive of the presence of this formidable barrier. Perhaps the pattern was influenced by the general hostility of the Late Pleistocene climate near the Cordillera. If that is the case, no relationship can be defended between this marginal use and the proximity of the Ice Cap. It must be remembered that the peopling of Patagonia basically took place under very cold conditions. The coincidence between the early Holocene peopling of the near-Cordillera zone and the warming trend of that time may not be coincidental. This is precisely the time at which a general intensification in the use of several sites took place in the different habitats across Patagonia (Borrero 1994–1995).

Discussion

Two main properties of the Late Pleistocene populations and habitats must be remarked. In the first place, all the abilities and technologies necessary to exploit those habitats near the Cordillera – including bifacial reduction, production of blades, housing and hunting technologies – were in place when the first humans arrived to Patagonia (Borrero 2001). In the second place, the lands in which the earlier sites were recorded were available since well before the arrival of humans. However, people just waited until the beginning of the Holocene to proceed in that direction.

The biogeographical perspective selected in this paper is based on the simple presence/absence of fauna within a regional space. Several significant patterns emerged from this analysis. The faunas at the steppe sites are dominated by guanaco (Mengoni Goñalons and Silveira 1976, Silveira 1979, Mengoni Goñalons 1999), since the remains of huemul only rarely are found away from the Cordillera (Díaz and Smith-Flueck 2000). The presence of huemul remains is one of the few clear marks of a local exploitation in the forest. But, even when huemul is present, with few exceptions (Mena 1991) most of the species are the same that characterize the steppe sites, especially guanaco. Thus, during the Holocene the faunal assemblages usually do not differ significantly from those recorded away from the Cordillera. Alternatively, the pattern recorded at sites near the Cordillera is one in which indications of contacts with the East are abundant.

On that basis, it is suggested that most of the 'dead ends' were geographically marginal, and were very rarely used by people before the extinction of Pleistocene megafauna. In contrast with the situation in the Patagonian steppes, where megafauna was usually exploited, the earliest occupations near the Cordillera are characterized by the exploitation of modern faunas. Perhaps this pattern is a demographic artifact resulting from the slow expansion of people to the South. There is a very clear archaeological signal of Late Pleistocene human presence at Ultima Esperanza, on the Pacific side of the Cordillera (Nami 1987, Prieto 1991). The main difference between Ultima Esperanza and other near-Cordillera zones is that at Ultima Esperanza the Cordillera does not exist, and that the humans arriving there enjoyed a free lowlands corridor that communicated the Atlantic with the Pacific basins.

Conclusions

In the particular case of Patagonia most of the 'dead ends' did not support discrete populations. As we saw, most of the human occupations recorded near the Cordillera were explained as the result of logistic use from population cores located in the East. The presence of secondary corridors – with an East-West axis – is implied, and spatial discontinuity between the Eastern and Western archaeological expressions of these populations can be defended. On that basis, we properly may term those occupations –not the populations – 'marginal'.

These lands were marginal in relation with the main Eastern population cores and with the main circulation corridors in Patagonia, which were near the coast, or even – at least seasonally – in the plateaus. This panorama is contrary to that proposed by Martinic (1993), who sugsted that the process of peopling of Patagonia took place following a near-Cordillera corridor.

Indeed, there is still a question of degrees of marginality that remains open. It must be mentioned that Mena considered the possibility that a separate population was using the Ibañez valley (Mena 1999), and Aschero evaluated the suggestion that the Parque Nacional Perito Moreno was used in winter (1981–1982). These are valid alternatives in necessity of relevant research. A paper by Franco and Civalero compared CCP7 and Chorrillo Malo 2, both important sites located in two of the regions discussed in this chapter. They found that lithic artifacts and raw materials provenience matched the expectations provided by Borrero's (1994–1995) model of exploration and early colonization of Patagonia (Civalero and Franco 2002). A difference between both sites is the higher depositional rate of tools at the lower layers of CCP7, a condition that

may be influenced by the vicinity of a first class obsidian source at Pampa del Asador, only 40 km East of the site (Civalero y Franco 2002). However, it may still be the case that the situation in the Parque Nacional Perito Moreno is different from that recorded South of Lago Argentino.

In sum, the marginal use of some 'dead ends' during the Late Pleistocene-Early Holocene appears to be an artifact of a step-by-step process of peopling, in which the locations away from the main circulation routes were populated lately. During the early Holocene, after the disappearance of the megafauna, the human presence is well attested. At the beginning of the Late Holocene, some of the near-Cordillera spaces were more intensively used, but always within a logistic mode of exploitation. Finally, during the Late Holocene, probably under conditions of high human demography, some of the areas – the Parque Nacional Perito Moreno – were more continuously occupied. At this time, then, the use of some of the 'dead ends' was better integrated within the human home ranges. Other areas, like Lago Argentino, remained marginal until the historic period.

It is very difficult to sustain that separate biologically viable populations were occupying the space of some of those 'dead ends' – including the case of the Ibañez. Instead, discontinuous occupations by people whose main population cores were installed in the East is the most economic way to explain the evidence. This amounts to cataloguing those 'dead ends' as truly marginal lands within the vast area known as Patagonia.

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9. The Highs and Lows of High Arctic Mammals: Temporal Change and Regional Variability in Paleoeskimo Subsistence

Christyann M. Darwent

The High Arctic of Canada and Greenland was first inhabited approximately 4000 years ago during a climatically warm period. Faunal remains from 30 Paleoeskimo (4200–1000 BP) archaeological assemblages were identified and compared to remains from an additional 38 reported zooarchaeological assemblages. Shifts in prey indices, mammalian evenness values, and gaps in occupation appear to closely follow climatic change from initial occupation to the beginning of the Late Dorset period (1500–1000 BP). More pursuit time was concentrated on a few densely (locally) occurring taxa during Pre-Dorset and Early Dorset (4000–2000 BP) and shifts in faunal assemblage composition are tied closely to shifts in climate prior to abandonment of this region at the end of Early Dorset. As climate cooled, Paleoeskimo hunters adapted to this change by shifting to ringed seals. Given that the High Arctic was reoccupied in Late Dorset during relatively warmer climatic conditions, climate alone does not adequately explain the variability in Late Dorset faunal assemblages and the relative decline in artiodactyls (muskox/caribou). A relative shift from higher-benefit artiodactyls and seals to lower-benefit fox and hare, and a shift to broader and more varied taxa, suggests resource depression in Late Dorset concomitant with decreased mobility and relatively higher localized population density.

The High Arctic is a marginal, inhospitable, and unforgiving environment; however, it is bountiful enough to have sustained the most northern human occupation on the globe. Although the inhabitants of the High Arctic may not have regarded themselves as marginal or living on the fringe, others might have described them as such. The Polar Eskimo or Inughuit of northwestern Greenland were, for example, one of the last groups in North America to encounter western civilization (Ross 1819). As an archaeologist, this part of the world continues to be one of the most difficult places to conduct fieldwork because of its remoteness, demanding weather conditions, and complex and costly logistics.

Marginality is defined by Webster's dictionary as 'a limit to what is desirable or possible' and as 'a border, edge, or brink.' These definitions describe the High Arctic, both in a geographic and in a cultural sense. This region is also characterized by its remoteness, insularity, and extreme climate – of which typify biogeographic marginality (*e.g.* Brown and Lomolino 1998; Cox and Moore 1985). Prehistoric populations often have been painted with a broad brush stroke, with little allowance for behavioral variability in how humans subsisted in this region. Using the zooarchaeological record, this paper illuminates the temporal and regional differences in hunting patterns during the Paleoeskimo period (*c.* 4000–1000 BP) of High Arctic prehistory.

The first occupants of the High Arctic of Canada and Greenland are believed to have derived from the west – most likely originating with the early *Arctic Small Tool tradition* in northern Alaska – approximately 4000–4500 years ago (Giddings 1964; Irving 1957; Maxwell 1985) during what is generally considered a warm period. Arctic researchers (*e.g.* Barry *et al.* 1977; Fitzhugh 1997) have long discussed cultural responses to changes in climate and how these responses are primarily the result of the way climatic change affects the distribution and density of animal resources.

Previous research in the High Arctic focused on the description of faunal remains from single sites (*e.g.* Bendix 1998; Darwent 1995) or from multiple sites in a small subregion (*e.g.* McCartney 1989; Schlederman 1990). However, I am interested in elucidating the *variability* in Paleoeskimo diet, which requires numerous

faunal assemblages from different temporal periods and geographic locales within the High Arctic. In this study I conduct a large-scale synthesis of High Arctic Paleoeskimo (*c.* 4200–1000 BP) prehistory from a zooarchaeological perspective in order to investigate variation across space and changes through time in the relative frequency of vertebrate taxa in faunal assemblages, including whether dogs were part of their lifeways. I explore similarities and differences in prey rank, relative abundances of mammals, and taxonomic evenness in mammalian assemblages.

Granting the resource limitations of a polar-desert environment, I test the notion that there was a shift in emphasis away from less stable terrestrial resources and toward more stable marine resources over time, including an increased use of walrus (*e.g.* Maxwell 1985; Murray 1996, 1999). Abiotic parameters such as precipitation, temperature, and wind are known to have a negative effect on terrestrial mammal, population density and distribution – particularly artiodactyls (*e.g.* Forchhammer and Boertmann 1993; Parker *et al.* 1975; Vibe 1958, 1967). Marine environments tend to act as a buffer against *minor* climatic changes, and as such, populations of marine mammals are affected less adversely.

Animal-bone assemblages are the product of two agencies: (1) human decisions concerning what to hunt and what parts of the animals to bring to the site and (2) various destructive agencies that destroy bones before archaeologists can study them. The effects of both agencies on a bone also depend on the structure and density of the individual bone. Taphonomy, or the study of the transition of organic material from the living realm into the geological realm (Efremov 1940), and the investigation of prehistoric subsistence are thus fundamentally linked. Given this fact, understanding the formation of the archaeofaunal record is a necessary component of zooarchaeological research (*e.g.* Lyman 1994). I examined sample size, differential fragmentation, and differential body part representation, or density mediated destruction, in High Arctic Paleoeskimo faunal assemblages to understand how these factors might influence interpretations of dietary change. To minimize taphonomic biases, assemblages that were not suitable for one or another of the above reasons were *not* included in the overall interpretation of temporal and/or geographical trends (see Darwent 2001 for full discussion).

Environment and Prehistory

The High Arctic of Canada and Greenland is located within a broader region known as the *Eastern Arctic* (Fig. 1). Following convention (*e.g.* Maxwell 1985; McGhee 1998) the High Arctic is defined here as the Canadian Arctic archipelago and Greenland north of Parry Channel and Lancaster Sound, or north of 75º N latitude. Over 95% of the ice-free land area of the High Arctic is represented by polar deserts and semi-deserts (Bliss *et al.* 1973). This region is characterized by low precipitation, by diminutive and low-density vegetation, and by only two seasons – long cold winters and short cool summers (Bliss *et al.* 1973; Miller *et al.* 1977). Mean temperatures usually do not rise above 0° C until mid-June, and winter begins when the mean temperature dips below freezing in mid-September (Miller *et al.* 1977).

Approximately 5000–5500 years ago the Central Canadian Arctic was free of most glacial ice (Dyke and Prest 1987), which had covered the region during the last glacial advance. Glaciers and permanent snow fields on both Greenland and the eastern margin of the Canadian Arctic are remnants of the Pleistocene. Although their margins are treeless tundra, they provide a higher density of vegetation than other areas of the High Arctic and thus tend to support larger ungulate herds. These regions also attracted human occupants.

Polynyas, or areas of permanent open water created by variations in ocean currents (like a lake in the sea ice), stay open even through the coldest winter months – albeit smaller in size than during the warm season. In the summer, polynyas attract migratory birds and other marine-oriented fauna, including humans (Schledermann 1980). The most impressive of these is the 'North Water' polynya, located between northeastern Ellesmere Island and northwestern Greenland, which can extend south into the mouth of Lancaster Sound under favorable weather conditions (Stirling 1980).

Eastern Arctic prehistory can be divided into two major stages – Paleoeskimo and Neoeskimo (Maxwell 1976, 1985). The latter stage dates from 1000 years ago and is typified by active whale hunting, whale-bone and sod architecture, and the use of open-water boats, or *umiaks*. My study focuses on the earlier Paleoeskimo stage and changes in subsistence economies over the first 3000 years of High Arctic occupation. The Paleoeskimo stage is traditionally divided into Early Paleoeskimo, or Pre-Dorset; and Late Paleoeskimo, or Dorset (Maxwell 1976, 1985). Following Helmer (1994) I have divided the Paleoeskimo stage into four periods (Fig. 2).

Characteristic of the Paleoeskimo stage is a long lineage of small lithic artifacts – referred to as the Arctic Small Tool tradition – that includes microblades, microcores, burin spalls, and triangular-shaped harpoon endblades. Dwellings are stone-ringed and often contain stone-slab-defined midpassages interpreted as food-preparation islands because they typically contain charred blubber, hearths, and/or food debris. Late in the Paleoeskimo stage there was a florescence of tiny ivory, antler, bone, wood, and steatite carvings in human and animal form.

Included in Fig. 2 is a summary of the major warming and cooling trends for the North American Arctic (adapted from Barry *et al.* 1977; Fitzhugh 1997). An episode of relative warmth occurred between 4500 and 3500 BP, followed by a period of cooling culminating in

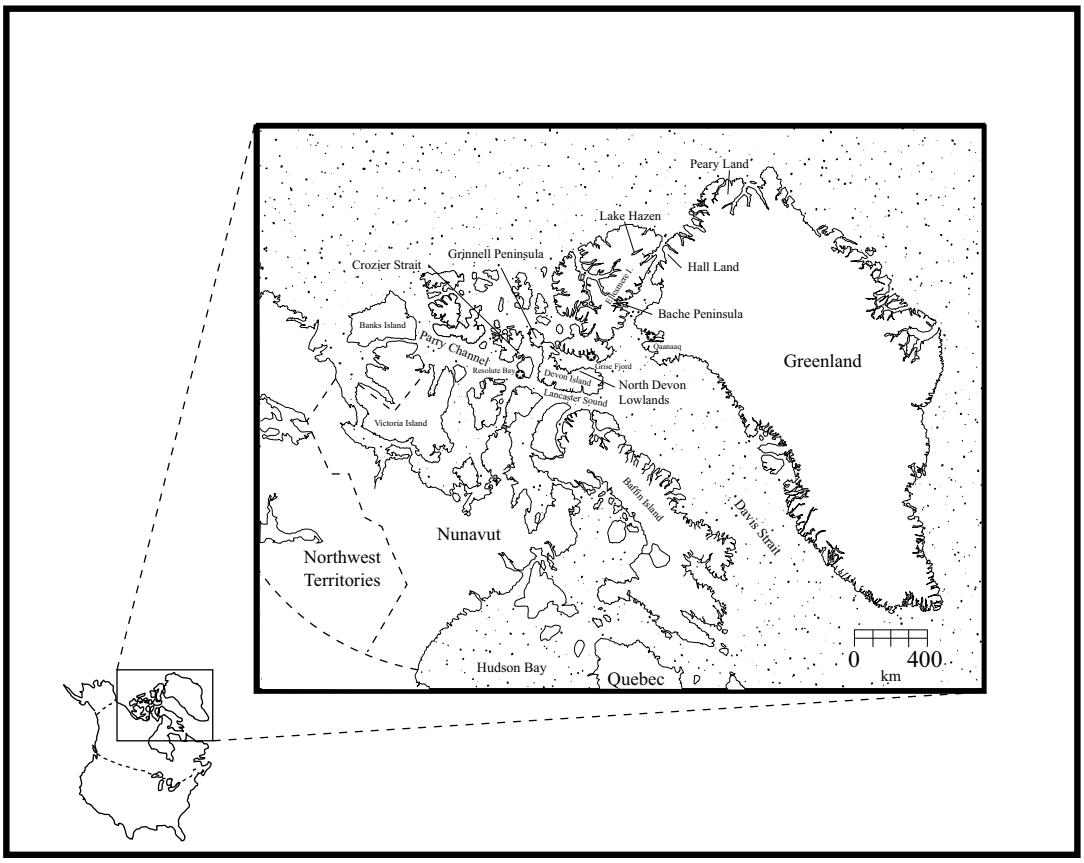

Fig. 1. The Eastern Arctic.

Early Paleoeskimo			
Period 1	4200–3600 BP	initial and Early Pre-Dorset	Warm (condition relative to present)
Period 2	3600–2800 BP	Middle and Late Pre-Dorset	Cooling followed by minor warming
Late Paleoeskimo			
Period 3	2800–2000 BP	transitional and Early Dorset	Cold transition/cold dry (*Neoglaciation*)
Period 4	2000–1000 BP	Middle and Late Dorset	Cold followed by warming (*Medieval Warm Period*, *c.* 1700–800 BP)

Fig. 2. Temporal, cultural, and climatic framework for Eastern Arctic Paleoeskimo sites (Andrews 1984; Barry et al. *1977; Dahl-Jensen* et al. *1998; Dansgaard* et al. *1969; Fitzhugh 1997; Hasholt 2000; Helmer 1994; Meese* et al. *1994; Willemse and Törnqvist 1999). Dates are presented in uncalibrated radiocarbon years before present.*

the Neoglaciation at 3200 ± 600 BP (Barry *et al.* 1977). Marked cooling and drying occurred about 2500–2000 BP, as recorded by significant changes in pollen and sand diagrams from lakes on Baffin Island (Andrews 1984), followed by a warming trend beginning around 1600 BP. This warming trend – the Medieval Warm Period – continued until about 800 BP and is corroborated by data generated from oxygen-18 concentrations (*i.e.* higher $\delta^{18}O$ concentrations indicate warmer climatic conditions) in ice cores from the Greenland ice sheet (Dahl-Jensen *et al.* 1998; Dansgaard *et al.* 1969; Meese *et al.* 1994), from sedimentary lake records from West Greenland (Willemse and Törnqvist 1999), and from macrobotanical and insect remains from South East Greenland (Hasholt 2000).

Paleoeskimo occupation of the High Arctic is characterized by two major temporal gaps. The first of these gaps occurs in northern and northwestern Greenland during Period 2, or between Independence I and II (Andreasen 1998; Knuth 1967, 1981, 1983). At two standard deviations the latest initial occupation of northern Greenland is 3400 BP. The earliest reoccupation of the region did not occur until 3280–2810 BP. This gap of up to 1000 years, roughly coincides with climatic cooling (Neoglaciation), which likely had an adverse effect on terrestrial fauna in particular. However, the gap

is a local event and does not occur in the *Canadian* High Arctic. The Bache Peninsula, North Devon Lowlands, and Grinnell Peninsula regions all have Early (Period 1) and Late Pre-Dorset (Period 2) occupations. Reoccupation of northern Greenland at the start of Period 3 is associated with a minor climatic warming period approximately 3000–2800 years ago (*e.g.* Barry *et al.* 1977; Fitzhugh 1997).

The second major gap occurs during the first half of Period 4, or Middle Dorset, when the *entire* High Arctic was apparently abandoned (Maxwell 1985); at two standard deviations, the latest occupation of the High Arctic occurred around 2050 BP. Middle Dorset is characterized as either cold or climatically unstable. Warming and High Arctic reoccupation did not take place until approximately 1700 years ago and coincides with the beginning of Late Dorset (Fitzhugh 1997) – a period that lasted for at least 660 years.

Materials and Methods

The zooarchaeological samples I use derive from materials collected over the past 50 years by researchers working in northern and northwestern Greenland and in the Canadian High Arctic islands (Fig. 3, Fig. 4). Collections I excavated and examined during the course of my investigations consist of over 32,000 specimens from 26 sites in Greenland (excavated by Eigil Knuth [1967, 1981, 1983] and collections stored at the Zoological Museum, University of Copenhagen) and four sites in Canada. I compared these with over 58,000 specimens reported from two sites in Greenland and 36 sites in Canada. Over 41,000 specimens from 68 temporally distinct assemblages were identified to genus or species of mammal. Data generated from these assemblages are used to document changes through time and variation across space in the use of animal resources in the Eastern High Arctic (Darwent 2001).

Two readily apparent differences across Paleoeskimo periods are found among the average assemblage size per site and among the number of sites investigated for each period (Fig. 5). More than double the number of specimens have been identified from Period 4 sites compared with Period 1, but nearly half the number of sites has been excavated. There is no correlation between the number of identified specimens (NISP) and Paleoeskimo period, or time (Spearman's rho = 0.40, P = 0.60); nor is there a correlation between NISP and the number of sites sampled per period (rho = –0.40, P = 0.60). However, there *is* an apparent correlation between cooler climatic conditions and the average number of identified specimens, or lower ΣNISP, *if* these faunal assemblages can be taken as representative of Paleoeskimo occupation in the High Arctic (*i.e.* the average number of specimens per site is lowest in Period 3). To minimize problems associated with differential identification of bird remains, and typically poor preservation of fish remains, I focus the remainder of my analyses on mammalian remains.

Results

Dogs in Paleoeskimo Assemblages

Dogs are typically conceived as being a necessary part of arctic life. However, the number of dogs or wolves in Paleoeskimo assemblages in the High Arctic is extremely low (44 specimens have been identified), comprising just under 0.1% of all classified mammalian remains (NISP = 45,532). All of these specimens are from Canadian High Arctic archaeological deposits, and none of these bone and tooth fragments were diagnostic to species. Even *if* all specimens recovered *are* the remains of domestic dog, their low frequency implies they were such a limited part of Paleoeskimo economies in this part of the Eastern Arctic that they are nearly invisible in the archaeological record.

Carnivore gnawing of any kind is extremely rare in High Arctic Paleoeskimo assemblages, and, as I discussed previously, dog remains are also rare. Of the four Late Dorset (Period 4) assemblages I examined from the Central Canadian High Arctic, 336 bones (2.6% of combined mammalian assemblage) have small fox-size carnivore gnaw marks and only *two* marks were produced by a dog/wolf-size carnivore (Darwent 2001).

McGhee (1998, 146) states that 'dogs are the first members of an Arctic camp to suffer during a period of food shortage, and frequent or periodic episodes of starvation may have kept the dog population low,' or in the case of the High Arctic, possibly nonexistent. In addition, there is no archaeological evidence of dogsleds or harnessing equipment (Maxwell 1985; McGhee 1998) during the Paleoeskimo stage of Eastern Arctic prehistory. Given these lines of evidence, it is doubtful that dogs provided much if any assistance to Paleoeskimo hunters in the High Arctic. Recent research on Paleoeskimo dogs in the Eastern Arctic as a whole (Morey and Aaris-Sørensen 2002) reveals they are exceedingly limited and found in isolated patches until Neoeskimo migration into the area around 1000 years ago when dogs become a widespread part of arctic culture.

Assemblage Evenness

Evenness is a measure of the distribution of specimens across taxa (*e.g.* Grayson and Delpech 1998; Grayson *et al.* 2001). Measurement of evenness allows one to address the question: Are all taxa contributing evenly to the assemblage, or is the assemblage dominated by one taxon or a few taxa. Here evenness is calculated as:

$$-\Sigma\, p_i \ln p_i \,/\, \ln (\text{Ntaxa})$$

Map #	Period	Site	Locality	Reference
1	1	Adam C. Knuth	J. V. Jensen Land, Greenland	Darwent 2001 (unpublished data, J. Møhl ZMK43/1986)
2	1	Bob's site	Peary Land, Greenland	Darwent 2001
3	1 & 3	Deltaterrasserne	Peary Land, Greenland	Darwent 2001
4	1	Galleriet	Peary Land, Greenland	Darwent 2001
5	1	Gammel Strand	Peary Land, Greenland	Darwent 2001
6	1	Kap Peter Henrik	Peary Land, Greenland	Darwent 2001
7	1	Killebukhus	Peary Land, Greenland	Darwent 2001
8	1	Kølterrasserne	Peary Land, Greenland	Darwent 2001
9	1	Lagunehøj	Peary Land, Greenland	Darwent 2001
10	1	Midternæs	Peary Land, Greenland	Darwent 2001
11	1	Pearylandville	Peary Land, Greenland	Darwent 2001
12	1	Portfjældt	Peary Land, Greenland	Darwent 2001
13	1	Solbakken	Hall Land, Greenland	Darwent 2001
14	1	Søhuset	Peary Land, Greenland	Darwent 2001
15	1	Tokanten	Peary Land, Greenland	Darwent 2001
16	1 & 3	Vandfaldsnæs	Peary Land, Greenland	Darwent 2001
17	1	Vendenæs	Peary Land, Greenland	Darwent 2001
18	1	Walcott Delta	Peary Land, Greenland	Darwent 2001
19	1	Cold (RbJu-1)	Devon Island, Canada	McGhee 1979
20	1	Upper Beaches (RbJu-1)	Devon Island, Canada	McGhee 1979
21	1	Icy Bay (QkHl-5:2,3)	Devon Island, Canada	McCartney 1989
22	1	Icebreaker Beach (QkHn-13)	Devon Island, Canada	McCartney 1989
23	1	Hind (QkHn-38)	Devon Island, Canada	McCartney 1989
24	1	Skræling ASTt-7 (SfFk-12)	Ellesmere Island, Canada	Schledermann 1990
25	1	Bight (SgFm-16)	Ellesmere Island, Canada	Schledermann 1990
26	1	Westwind	Ellesmere Island, Canada	Balkwill n.d.
27	1	Daylight	Ellesmere Island, Canada	Balkwill n.d.
28	2	Gull Cliff (RbJu-1)	Devon Island, Canada	McGhee 1979
29	2	Icy Bay (QkHl-5:1)	Devon Island, Canada	McCartney 1989
30	2	Field School (QkHn-12)	Devon Island, Canada	McCartney 1989
31	2	Twin Ponds (QkHn-17)	Devon Island, Canada	McCartney 1989
32	2	Rocky Point (QkHn-27)	Devon Island, Canada	McCartney 1989
33	2	Ridge (SgFm-6)	Ellesmere Island, Canada	Schledermann 1990
34	2	Rastoden (SfFl-10)	Ellesmere Island, Canada	Schledermann 1990
35	3	Engnæs	Peary Land, Greenland	Darwent 2001
36	3	Genbonæs	Peary Land, Greenland	Darwent 2001
37	3	Hellebæk	Peary Land, Greenland	Darwent 2001
38	3	Kap Harald Moltke	Peary Land, Greenland	Darwent 2001
39	3	Kap Ludovika	Peary Land, Greenland	Darwent 2001
40	3	Kap Mylius-Erichsen	Peary Land, Greenland	Darwent 2001
41	3	Lolland Sø	Peary Land, Greenland	Darwent 2001
42	3	QiLf-4	Kalivik Island, Canada	Helmer 1981
43	3	QjLd-2	Kalivik Island, Canada	Helmer 1981
44	3	QjLd-14	Kalivik Island, Canada	Helmer 1981
45	3	QjLd-21	Kalivik Island, Canada	Helmer 1981
46	3	QjLd-22	Kalivik Island, Canada	Helmer 1981
47	3	QjLd-24	Kalivik Island, Canada	Helmer 1981
48	3	Baculum (SfFl-1)	Ellesmere Island, Canada	Schledermann 1990
49	3	Grave Rib (SfFk-15)	Ellesmere Island, Canada	Schledermann 1990
50	3	Shelf (SgFm-18)	Ellesmere Island, Canada	Schledermann 1990
51	3	Tusk (SfFk-6)	Ellesmere Island, Canada	Schledermann 1990
52	4	QiLf-25	Kalivik Island, Canada	Helmer 1981
53	4	QjLd-17	Kalivik Island, Canada	Helmer 1981
54	4	QjLd-25	Kalivik Island, Canada	Helmer 1981

Fig. 3. High Arctic archaeological faunal assemblages used in this study. ZMK refers to the Zoologisk Museum København archival records.

where p_i is the proportion of specimens in the *i*-th taxon, which is multiplied by the natural log of p_i. The values calculated for each taxon are added – with the negative sign in the equation used to eliminate the negative values produced by the natural log transformations – and the sum (Σ) of these values is divided by the natural log of the number of non-overlapping taxa (Ntaxa). This index varies from 0 to 1. An evenness value of 1 indicates that all taxa are equally common in an assemblage, whereas the closer the value is to 0 the more an assemblage is dominated by few taxa or a single taxon.

Because I only use mammalian assemblages with NISP

Fig. 3. continued.

Map #	Period	Site	Locality	Reference
55	4	QiLa-3	Little Cornwallis Island, Canada	Darwent 2001
56	4	Arvik (QjJx-1)	Little Cornwallis Island, Canada	Darwent 2001
57	4	Tasiarulik (QjJx-10)	Little Cornwallis Island, Canada	Darwent 1995, 2001
58	4	Lea Point (RcHh-1)	Ellesmere Island, Canada	Darwent 2001
59	4	Cove (SgFm-5)	Ellesmere Island, Canada	Schledermann 1990
60	4	Longhouse (SgFm-3)	Ellesmere Island, Canada	Schledermann 1990
61	4	Franklin Pierce (SiFi-4)	Ellesmere Island, Canada	Schledermann 1990
62	4	Narrows (SgFm-12)	Ellesmere Island, Canada	Schledermann 1990
63	4	Oldsquaw (SfFk-18)	Ellesmere Island, Canada	Schledermann 1990
64	4	Shelter (SgFm-17)	Ellesmere Island, Canada	Schledermann 1990
65	4	Lauge Koch's Hus	Hall Land, Greenland	Darwent 2001
66	4	Qeqertaaraq	Inglefield Land, Greenland	Bendix 1998

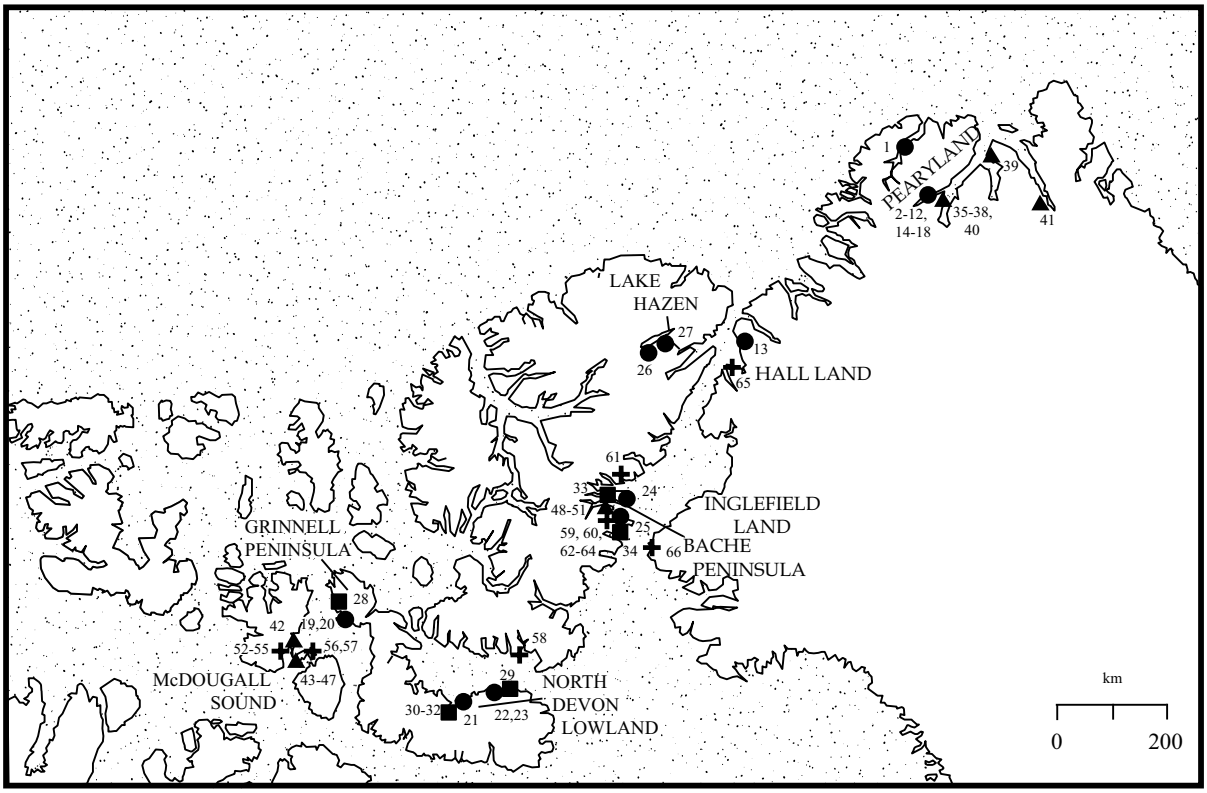

Fig. 4. Faunal assemblage localities.

=100, several sites with associated radiocarbon dates are eliminated from my sample. Also, my combined assemblages from northern Greenland have up to six associated dates, but numerous Canadian assemblages have no radiocarbon dates. Instead of averaging radiocarbon dates for some sites and using the median age of the Period for other sites, I chose to keep the assemblages in the Period to which they were assigned by the investigator – based either on radiocarbon dates, artifact typology, or some combination – and I treat these periods as ordinal variables.

Fig. 6 illustrates a weakly positive, but significant, trend toward greater mammalian evenness (rho = 0.38, $P = 0.07$) in coastal High Arctic assemblages and toward a broader range in the type and frequency of prey hunted. In addition, the relative frequency of ringed-seal remains per assemblage and assemblage evenness are strongly and negatively correlated across Period 1 through 3 ($r = -0.96$, $P<0.001$), such that as the number of ringed seals goes up evenness goes down. However, the correlation between these two variables does not hold for Period 4,

	Period 1	Period 2	Period 3	Period 4	Total
Fish	901 (33)	0	91 (5)	106 (7)	1098 (16)
Bird	2105 (78)	187 (27)	541 (29)	4278 (285)	7111 (105)
Mammal	12,525 (464)	2656 (379)	4136 (218)	26,215 (1748)	45,532 (670)
ΣNISP	15,531 (575)	2843 (406)	4768 (251)	30,599 (2040)	53,741 (790)
Total	29,122 (1079)	4524 (646)	8309 (437)	48,438 (3229)	90,393 (1330)
N of Sites	27	7	19	15	68

Fig. 5. Faunal specimens reported for each period of Paleoeskimo prehistory in the High Arctic. The total number includes unidentified specimens. Numbers in parentheses indicate the average number of specimens per site based on the total number of sites examined in a given period.

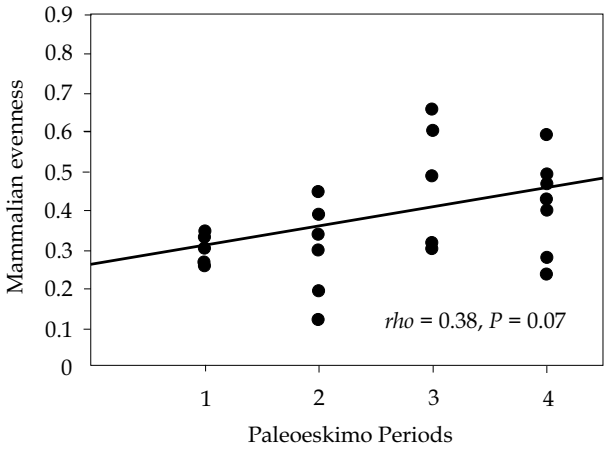

Fig. 6. Mammalian evenness across Paleoeskimo periods.

or Late Dorset, assemblages (r = –0.37, P = 0.37). Apparently, increased use of small terrestrial mammals is contributing to higher evenness values, and this increase in smaller-sized bone is not simply the result of larger assemblage size or preservation (Darwent 2001)

Ringed seals – nonmigratory inhabitants of the High Arctic – actually benefit from moderate environmental cooling (*e.g.* McLaren 1958; Smith and Hammill 1981), and as such there might have been higher populations of ringed seals during Period 2. The number of ringed seals is directly related to the amount of stable land fast ice – ice that is frozen to shorelines – available as breeding habitat. Smith and Hammill (1981, 980), from their observations on ringed seals, found that 'territorial behavior is seen to be involved in the partitioning of [fast ice] breeding habitat and is probably needed to provide adequate space for females to maintain effective birth lair complexes necessary in preventing mortality from predation.' A cooling period will produce winter fast ice more quickly and cover a larger area, providing a larger breeding habitat and decreased intraspecific competition; a cold period that produces ice *too* quickly, however, will limit the ability of ringed seals to scratch through the thick ice to maintain breathing holes. In addition, warming trends in the High Arctic might limit not only ringed seal breeding habitat, but also feeding areas under fast ice.

The relative increase in ringed seals from early Pre-Dorset to Early Dorset is related to overall changing climatic conditions that favored ringed seals. This culminated with abandonment of the High Arctic during the coldest period (end of early Dorset). When people returned to the High Arctic during a warmer period (beginning of Late Dorset) several hundred years later, they had changed their mobility patterns and brought with them more substantial house structures and communal longhouses. Rather than wandering from resource patch to resource patch, groups tended to remain in one location for longer periods intensively using all available resources within that area before relocating, which included increased use of fox and hare.

Some suggest (*e.g.* Maxwell 1985) there was a general trend away from terrestrial resources toward marine resources over time. This simplified description of Eastern Arctic prehistory masks much of the geographic variation in Paleoeskimo subsistence. McCartney and Helmer (1989) have suggested that the dual-economy model of a balance between terrestrial and marine resources (Taylor 1968), as derived from ethnographic description of the Central Inuit (*e.g.* Balikci 1970; Boas 1968), is not economically viable in the High Arctic given the biological limitations of artiodactyl populations. Hence the questions become: 1) what role did artiodactyls play in High Arctic subsistence, and 2) does a terrestrial resource need to be an artiodactyl?

Prey Indices

Marine mammals are of primary importance to coastal economies, particularly as they provide a readily accessible (*e.g.* Balikci 1970) and necessary (*e.g.* Mead *et al.* 1986; Speth 1987) supply of fat. In the High Arctic, marine mammals are also a more stable and reliable food resource than are caribou or muskox, which are highly subject to demographic pressures of over hunting and short-term climatic variation (*e.g.* Parker *et al.* 1975; Vibe 1967). These artiodactyls are a necessary source of skin, fur, and raw material and will tend to be taken

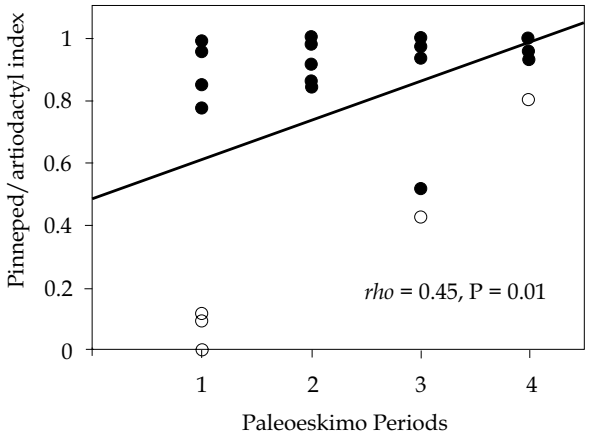

Fig. 7. Relation between pinniped/artiodactyl index values and Paleoeskimo periods. Open circles are northern Greenland assemblages.

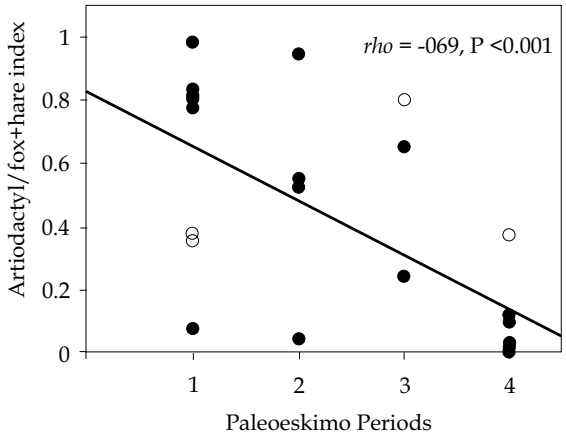

Fig. 8. Relation between artiodactyl/fox+hare index values and Paleoeskimo periods. Open circles are northern Greenland assemblages.

whenever encountered. However, since they could not always be relied on during all seasons, a "pinniped/ artiodactyl index" [Σ Pinnipeds$_i$ / Σ Artiodactyls$_i$] compares the relative abundance of seals plus walrus (pinnipeds) and caribou plus muskox (artiodactyls) within an assemblage (Fig. 7). The higher the index value the greater the contribution of pinnipeds to High Arctic Paleoeskimo economies. Differences in this index value over time might suggest change in climate, in hunting strategies, or in both.

The pinniped/artiodactyl index indicates a weak but positive trend away from caribou and muskox toward increasing reliance on seals and walrus over time (there is no correlation between this index and assemblage NISP [r = 0.26, P = 0.16]). The trend toward greater reliance on pinnipeds becomes insignificant (rho = 0.32, P = 0.13) if Greenland assemblages are removed, suggesting that artiodactyls were *never* a significant resource in *Canadian* High Arctic localities.

In the Eastern Low Arctic, Nagy (1997) examined faunal remains from the Arctic coast of Quebec and found virtually *no difference* in the relative contribution of terrestrial mammals to assemblages ranging from Late Pre-Dorset (Period 2) to Early Dorset (Period 3). Here, pinnipeds are the dominant taxa in all assemblages. On Igloolik Island, near southwest-central Baffin Island, however, the relative frequency of artiodactyls *increases* from Early Pre-Dorset (Period 1) through Early Dorset (Period 3) to Late Dorset (Period 4) (Murray 1996). Calculation of a 'pinniped/artiodactyl index' for these assemblages reveals a shift from 0.99 in Period 1, to 0.81 in Period 3, to 0.66 in Period 4; in other words an apparent *decrease* in the importance of walrus and seals relative to caribou in the Igloolik region.

I use an 'artiodactyl/fox+hare index' [Σ Artiodactyls$_i$ / Σ Artiodactyls$_i$ + Fox$_i$ + Hare$_i$] to summarize the relative contribution of muskox and caribou (artiodactyls) to the terrestrial mammal assemblage; the higher the index value the greater the contribution of artiodactyls. Based on their greater body size, muskox and caribou are 'higher-ranked' terrestrial prey species than are arctic fox or hare because the former produce a higher yield of food, skins, and raw materials (*e.g.* Bayham 1979, 1982; Broughton 1994a, 1994b, 1999; Butler 2000; Cannon 2000). Foraging theory predicts that given their higher yield, artiodactyls most likely will be taken whenever encountered; whereas the probability that fox and hare will be taken, with their lower return rates, will be dependant on the abundance of artiodactyls in the region.

Although the artiodactyl/fox + hare index is highly varied across assemblages (Fig. 8), there does appear to be a decrease in caribou/muskox use and increased use of fox/hare over time (rho = –0.69, P <0.001). The correlation between index values and time is not appreciably changed by omission of Greenland assemblages (rho = –0.73, P <0.001). This trend is driven partially by sample size; artiodactyls decrease relative to fox/hare, as sample size increases (r = –0.37, P = 0.08). Mostly, however, this trend is driven by the high frequency of arctic fox/ hare in Period 4, and when Period 4 assemblages are omitted there is no correlation between this index and time (rho = –0.25, P = 0.36). The artiodactyl/fox+hare index is more varied in Periods 1–3 than it is in Period 4 when all assemblages have a low index value. Overhunting of caribou and muskox, coupled with colder climatic conditions toward the end of Period 3 – prior to abandonment of the High Arctic – might have suppressed caribou and muskox populations to such an extent that they had not recovered by the time people reentered the High Arctic during the latter half of Period 4. This scenario also could explain the apparent absence of Period 4 (Late Dorset) sites in northern Greenland.

Fox and hare vary considerably in High Arctic Paleoeskimo assemblages, particularly in relation to pinnipeds.

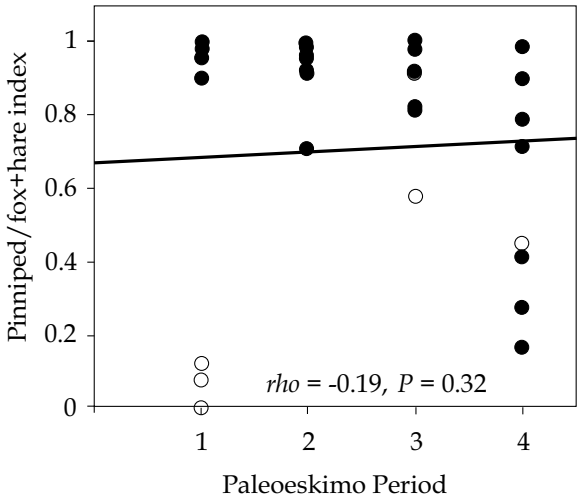

Fig. 9. Relation between pinniped/fox+hare index values and Paleoeskimo periods. Open circles are northern Greenland assemblages.

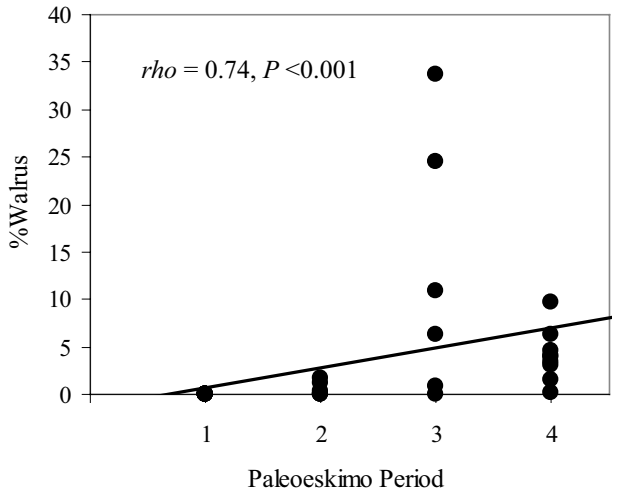

Fig. 10. Relative frequency of walrus in High Arctic mammalian assemblages.

To address the question of the importance of fox and hare in certain areas and at certain times, given that some faunal assemblages have few artiodactyl remains, I designed a third index. The relative contribution of pinnipeds and small terrestrial mammals (fox and hare) or the "pinniped/fox+hare index" is summarized as: [Σ Pinnipeds$_i$ / ΣPinnipeds$_i$ + Fox$_i$ + Hare$_i$]. This index is not correlated with temporal period (Fig. 9), nor is it correlated with sample size (r = –0.06, P = 0.76). If northern Greenland assemblages are removed, an apparent trend toward decreased use of pinnipeds relative to fox/hare emerges (rho = –0.57, P = 0.003); however, this trend is driven entirely by Period 4 assemblages, such that the relation between these taxa increases dramatically with no correlation between high values and geographic locality. Fox in particular became a valuable resource to High Arctic people at this time, perhaps as a replacement for artiodactyl furs and skins.

Period 4, or Late Dorset, sites are characterized by large semi-subterranean house structures, numerous caches, large midden deposits, and 'communal' longhouse structures. These characteristics suggest that duration of settlement at any one location was longer than during previous periods. Concomitantly, people were likely spending more time taking resources more intensively within a general foraging radius of their settlement (processors) during Period 4, rather than moving frequently from resource patch to resource patch (travelers) during Period 1–3 (*e.g.* Bettinger 1991; Bettinger and Baumhoff 1983).

Walrus in Paleoeskimo Assemblages

One of the most dramatic temporal changes in High Arctic subsistence is in the use of walrus. The beginning of the Dorset period is marked by the appearance of heavily constructed harpoon heads to which a thicker/stronger line could be attached – the Dorset Parallel type (Maxwell 1976; Murray 1996, 1999). The appearance of these harpoon heads is concomitant with the appearance of walrus in faunal assemblages. Compared with other pinnipeds, walrus are virtually nonexistent until Period 3 or Early Dorset (Fig. 10). Bearded seal remain relatively constant in their contribution to Paleoeskimo assemblages; however, walrus appear rather suddenly in the zooarchaeological record. There is no correlation between sample size and the relative frequency of walrus (r = -0.12, P = 0.88), indicating this increase is not the result of larger samples. This sudden appearance of walrus bones in faunal assemblages does not correlate with climatic warming or increased open-water leads. Walrus populations had not suddenly increased; rather, invention of better technology – *e.g.* the Dorset Parallel-type harpoon head – brought about their incorporation into Paleoeskimo diet. The relative decline in walrus during a subsequent warmer period may relate to overall broadening of the diet and more intensive use of local resources (*e.g.* ringed seals, fox and/or hare) and less focus on one particular, difficult to obtain marine resource.

Summary and Discussion

Artiodactyls are relatively low-ranked prey in Canadian coastal Paleoeskimo sites. The notion that caribou (or muskox) comprised a significant portion of an Arctic economy stems in part from ethnographic research conducted in lower regions of the Arctic (*e.g.* Balicki 1970; Boas 1964), thus use of these subsistence patterns as an analog for the High Arctic is untenable (McCartney and

Helmer 1989). What is apparent is that there was increased use of arctic fox in Period 4, and an *overall* increase in assemblage evenness through time. Arctic fox likely provided a substitute for artiodactyls in most regions of the Canadian High Arctic.

Within the pinniped order, relative abundances of bearded seals are nearly stable through time. Walrus bones, however, are virtually absent from Period 1 and 2 (Pre-Dorset) assemblages and appear rather suddenly in Period 3 (Early Dorset). Murray (1996, 1999) correlated a similar shift in the Low Arctic with better harpoon technology manifest as the Dorset Parallel form with its much thicker line-hole opening and sturdier construction.

Shifts in prey indices, mammalian evenness values, and gaps in occupation appear to closely follow climatic change from initial occupation to the beginning of Late Dorset. Pinniped and artiodactyl prey indices demonstrate that the relative contribution of marine resources to Canadian coastal assemblages decreases slightly relative to artiodactyls through the Paleoeskimo stage but both sets of taxa decrease significantly in relation to arctic fox/hare in Period 4. Mammalian assemblage evenness also increases in Period 4. This shift in Period 4 is associated with more substantial architecture, cache pits, and decreased mobility – and seems to reflect a shift from travelers to processors (Bettinger 1991). In other words, more pursuit time was concentrated on a few densely occurring species during Pre-Dorset and Early Dorset (Period 1–3), while more time was spent on processing a broader range of resources during Late Dorset (Period 4). Given that Late Dorset occupation of the High Arctic is associated with warmer climatic conditions, climate alone does not adequately explain the variability in Period 4 assemblages and the relative decline in artiodactyls. A relative shift from higher-benefit artiodactyls and pinnipeds to lower-benefit fox and hare suggests resource depression. Depression of resources has been documented archaeologically in other regions and is typically concomitant with increased population density and decreased mobility (*e.g.* Bayham 1979; Broughton 1994a, 1994b, 1997, 1999; Cannon 2000; Stiner *et al.* 1999). In addition to these shifts, walrus remains increase from less than 1% of High Arctic mammalian assemblages in Pre-Dorset sites to an average of 8% in Dorset sites. This trend seems to be associated with more substantial harpoons and suggests communal hunting (Murray 1999).

Increased use of small arctic fur-bearers, and widening diet breadth occurred during Late Dorset (Period 4). Arctic fox, and to a lesser extent arctic hare, likely substituted for artiodactyls in areas where, given limited suitable resources, populations of large terrestrial animals could not be sustained. Implication of the prey indices is that if populations of artiodactyls decreased both in density and distribution because of abiotic factors, human predation of caribou and muskox could cause local populations to crash (given that herd size is small and these species are essentially nonmigratory). Local decreases in artiodactyl populations might force people to shift both to taking more small terrestrial taxa and to taking more, and larger, pinnipeds (*e.g.* walrus).

A shift in subsistence during final reoccupation of the High Arctic by Paleoeskimo groups is associated with more substantial architecture, cache pits, and decreased mobility, and seems to reflect a shift to more intensive use of mammalian resources in a particular area. Given that Late Dorset occupation of the High Arctic is associated with warmer climatic conditions, the Medieval Warm Period, climate alone does not adequately explain the variability in Late Dorset assemblages and the decline in artiodactyls.

Intensive use of resources toward the end of the Paleoeskimo stage of Arctic prehistory could have caused a decline in the resource base, which begs the suggestion that Late Dorset populations simply could not compete with the arrival of Thule (Neoeskimo) migrants and their dogs from Alaska about 1000 years ago. Technology and dog transport sported by Thule folk allowed them to tap previously unexploited whale resources, which would have been a food and raw material source not reduced by intensive Paleoeskimo hunting. Mammalian resource depression coincident with the arrival of Thule whale-hunters likely resulted in demise of the Paleoeskimo way of life.

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10. Identifying Dietary Stress in Marginal Environments: Bone Fats, Optimal Foraging Theory and the Seasonal Round

Alan K. Outram

The importance of fat in the diet is outlined and the importance of bones as a reliable source of fat is explained. Different patterns of bone marrow and grease exploitation are discussed with particular reference to marginal environments and how levels of exploitation will be related to levels of dietary stress. The possible role of Optimal Foraging Theory in addressing this issue is outlined and adaptations of Marginal Value Theorem and Diet Breadth specific to bone fat exploitation are put forward and described. The methodologies for studying patterns of bone fat exploitation within archaeological assemblages are outlined and four example applications relating to Norse and Paleo-Eskimo Greenland, Norse Iceland and Middle Neolithic Gotland are used to illustrate what these methods can show. These case studies are discussed with specific reference to identifying dietary stress in marginal environments and the role of seasonality to this issue.

Introduction

The importance of fat has often been underestimated in zooarchaeological studies, with more attention being paid to the acquisition of meat. This is not because information on the essential role that fats play in the diet has not been documented or because the subject has lacked academic champions, but is probably more related to Western society's subconsciously negative view of fat in terms of both health and body image. This negative view of fat is, of course, a relatively modern phenomenon that really only gained momentum within the 1960's (Beardsworth and Keil 1997, 176).

In terms of energy, fat can provide 225% the number of calories compared to equal quantities of either carbohydrate or protein (Mead *et al*. 1986; Erasmus 1986). Within subsistence economies, therefore, sources of fat are likely to be very highly valued. Within economically marginal environments operating marginal subsistence economies the full exploitation of available fat resources may make the difference between the viability of that society and starvation. In dietary terms, fat becomes an even more important resource when reliable sources of carbohydrate are absent. Speth (1983; 1987; 1991) and Speth and Spielmann (1983) made a highly significant contribution to archaeologists' understanding of this issue with their work on the body's reaction to high protein diets. If the body is reliant upon protein for almost all its energy, amino acids are broken down to meet energy needs rather than fulfilling their normal function of replenishing body protein. In severe cases, existing muscle protein will also be broken down. Very high protein diets are, therefore, very dangerous. Carbohydrates are best at averting this metabolic problem (Speth and Spielmann 1983, 14), but in many environmental and economic regimes, sources of carbohydrate are almost totally absent and, therefore, an adequate supply of dietary fat becomes essential. Speth and Spielmann (1983, 4) cite several ethnographic and historical examples of hunters' practical awareness of this problem. Another important dietary issue is that small quantities of certain types of fat are required within the diet for the proper functioning of the body. These are referred to as 'essential fatty acids' (Erasmus 1986; Mead *et al*. 1986). Furthermore, fats can be important in the supply of lipid-soluble vitamins such as A, D, E, and K (Mead *et al*. 1986, 459). So, it can be clearly demonstrated that the levels of fat exploitation within subsistence economies can be critical and all the more critical in economies dependant upon animal products (hunting or pastoral economies) due to the limited availability of carbohydrate under such regimes. The more marginal the economy, in terms of meeting calorific needs, the more essential fat becomes.

Dietary fat can be obtained from a number of sources. Plant foods, particularly nuts, can provide dietary fats, but much larger quantities are available from animal products. Fat can be found within meat and in quite rich quantities in dairy products, but also in almost pure form in the depot fats to be found under the skin (adipose fat) and within bones (marrow fat and bone grease). If one is to study the exploitation of animal fats archaeologically, the best option is to concentrate upon bone fats. There are a number of reasons for this.

Firstly, bones frequently survive archaeologically and in order to exploit bone fats the bones need to be deliberately broken into. The exploitation of bone fats, therefore, leaves direct archaeological evidence. To exploit bone marrow, one needs to access the medullary cavity to be found in long-bone shafts and a few other elements. To exploit bone grease, one must break up bones into pieces and render them. The detailed patterns created by bone marrow and grease exploitation and how to recognise them are discussed in more detail below.

It is true that the presence of the bones also implies the presence of quantities of meat and adipose fats as well, but there is no direct evidence for their exploitation. In particular, it will not be clear just how much fat would have been present. The amount of adipose and meat fats to be found on an animal varies wildly in relation to season, health and life cycle. If one takes red deer (*Cervus elaphus*) as an example, though this point applies to most mammals, levels of 'rump fat' can be almost negligible for large parts of the year but there can be quite substantial reserves built up in particular seasons. A further complication is that the pattern is very different for males and females (Mitchell, McCowan and Nicholson 1976; Clutton-Brock and Albon 1989). Archaeological animal bone assemblages might also indicate the exploitation of animals for dairy products. This is a proxy indicator of the exploitation of animal fats, but a rather indirect and difficult to quantify one. The exploitation of bone fats themselves can be far more readily quantified by direct analysis.

The second reason for concentrating upon bone fats relates back to extreme variation in quantities of depot fats that can be seen in animals. Animals store depot fats as an energy reserve. When they need to call upon this reserve, they call upon some depots in preference to others. Within this 'fat-mobilization sequence', bone fats are usually the last reserve to be called upon (Cheatum 1949; Brookes *et al.* 1977; Peterson *et al.* 1982; Davis *et al.* 1987). In fact, in many cases, the animal could have died from starvation but still have significant levels of fat within its bones (Peterson *et al.* 1982, 550). Bones are, therefore, a very reliable source of fat when animals have little other fat in their bodies. Levels of fat within bones can change with the condition of animals, but not as drastically as other depots and only in a serious way when the animal is in a very poor state. As well as being a good source of fat to target, amounts of bone fat available can be more easily quantified than other fat sources. This can be done by employing indices calculated using modern specimens (see below for further discussion) or simply by quantification of amounts of archaeological bone present. Medullary cavities, that would have been filled with marrow fat, could, in theory, actually be measured. Brink (1997) found, during experimental studies of bison, that dry bone mass was an accurate predictor of an element's bone grease yield.

So far we have established that bones would be sort after as a reliable source of fat, that the amount of fat available is more quantifiable than other sources and that the exploitation of bone fats is more directly demonstrable within archaeological assemblages. The final, and key, reason for studying bone fat exploitation is that there is a clear rank order of utility within the resource. Different elements contain different amounts of marrow and grease. Marrow is easily exploited, whilst bone grease exploitation requires far more effort. There is a range of utility from bones with large medullary cavities, filled with fat, that can be accessed and consumed within seconds, to bones that contain very little fat but require much effort to obtain it. If one can successfully assess the extent to which bone fats are being exploited, one might have a very good indicator of the relative needs of people within different economies and environments. Given that bone fats are such an important resource, and their exploitation could be a matter of life and death, this type of study could be key in identifying economic and dietary stress and help us understand more about the palaeoeconomics of marginal environments.

Patterns of Bone Marrow and Grease Exploitation

The exploitation of bone marrow as a food is very well known and accounts of its use can be found within ethnographic accounts of a very wide range of peoples in very varied environments. For example, good descriptions of the use of bone marrow can be found in accounts of Inuit peoples (*e.g.* Binford 1978), Native Americans (*e.g.* Little Bear 1982), the peoples of Siberia (Levin and Potapov 1964), the Hadza of Tanzania (O'Connell and Hawkes 1988), the Kalahari San (Yellen 1991; Kent 1993) and Alyawara of Australia (O'Connell and Marshall 1989). One could probably obtain a decent account of the use of bone marrow from an elderly person in almost any culture in any part of the world. Bone marrow is found principally in the long bones, but also in very small cavities in other appendicular elements like phalanges and in larger quantities in the mandible. The pattern associated with its exploitation is simple; the bone's medullary cavity will have been deliberately broken into, whilst the bone is still in a relatively fresh condition (for detailed discussion see Outram 1998; 2002).

'Bone grease' refers to bone fat which is chemically much like the fat in medullary cavities but is trapped

Fig. 1. Caribou shaft cylinders from tibia (right) and metatarsals (left) from the Paleo-Eskimo site of Itivnera, Western Greenland (scale in 1cm divisions).

within the structure of the bone. The articular ends of long bones and almost all the axial skeleton are made up of spongy or 'cancellous' bone that contains much fat within its structure. This fat can only be easily extracted by breaking up cancellous bone into small pieces and boiling the pieces to melt the fat out. The fat will come to the surface of the water where it can be solidified as it cools and removed. A very detailed description of this process can be found in Binford's (1978) account of the Nunamiut, but there are also good accounts of very similar practices by the Loucheux Indians (Leechman 1951; 1954) and the Hidatsa (Wilson 1924). According to Binford (1978), the processing of bone for grease can be on a fairly industrial scale. Long bone ends and axial elements are saved up in piles until there are sufficient to make rendering worthwhile. Long bones are often broken next to the articulation at both the proximal and distal ends so that the marrow can be poked out for consumption and the ends saved up. This can produce many very deliberately created long bone cylinders. Such cylinders are present in very large numbers at the Paleo-Eskimo site of Itivnera in Greenland (Møhl 1972; Outram 1998; 1999), which can be seen pictured in Fig. 1. The axial and articular units are then comminuted into small pieces and boiled. This process is incredibly labour intensive, especially when compared to the amount of fat that can be obtained from marrow cavities following a single blow. The pattern created by this activity is fairly distinctive, in terms of what gets broken up into small pieces and what remains relatively unfragmented. Detailed discussion of these patterns can be found in Outram (1998; 2001a).

An issue of great importance is that there is a definite rank order to the exploitation of bone fat resources. With regard to marrow bones, it is clear that some bones have larger marrow cavities than others and the degree to which one bothers with the lesser resources is very dependent upon people's needs at the time. There is a traditional saying amongst the Nunamiut that says that "the wolf moves when he hears the Eskimo breaking mandible for marrow" (Binford 1978, 150). This is, in fact, well backed up by observations of the Nunamiut bone fat exploitation habits. Using Binford's records of Nunamiut marrow processing decisions and processing efficiencies, Jones and Metcalfe (1988, 422) made the calculation that it appears that the Nunamiut were, under normal conditions, unwilling to process elements that yielded less that 500 kcal/hr. This just excludes the mandible. The yield rate of elements and this cut-off point are displayed in Fig. 2.

With regard to bone grease, it is clear that different elements will contain different levels of grease, but there are other issues related to the rank order of grease production. Blood is created within bone marrow and bone marrow that contains a lot of blood is often referred to as red marrow. Red marrow contains less fat and more protein. In adult animals red marrow is concentrated within the cancellous tissues of the skull, ribs and vertebrae, whilst most of the marrow in long bones is principally fat (Rixson 2000, 11). This makes the long bone ends better for bone grease production than axial elements. This distinction can be seen in the ethnographic accounts. Binford (1978, 32) notes that appendicular and axial elements are stored and processed separately and there is a preference for the use of the appendicular bone grease. This distinction is backed up by Wilson (1924), with reference to the Hidatsa. Binford (1978, 146) also notes that in times of desperation, the Nunamiut also resort to the rendering of dense shaft fragments, which yield very little indeed.

The implication of these patterns is clear. The choices people make about which types of bone to process and how much of them to process can tell us much about the state of their subsistence economy and indicate whether they are suffering from dietary stress or not. If evidence of such activities is preserved archaeologically and can be identified and quantified, then there is great potential for understanding the extent of subsistence stress amongst people apparently living in marginal environments.

Using Optimal Foraging Theory as a Framework

The above discussion of resource ranking implies that something akin to optimal foraging theory (OFT) needs to be applied to the study of bone grease exploitation. Below is a discussion of how bone fat exploitation decisions might fit in with existent OFT models.

There are two selective processes that need to be considered with regard to bone fat exploitation strategies. Firstly, if the animal or animals to be exploited have been killed some distance from the site where fat processing will take place, one has to consider element transport choices. One needs to understand which fat resources arrived at the site in order to understand the selection for fat processing. Also, the transport decisions themselves might relate to economic strategy (see Binford 1978).

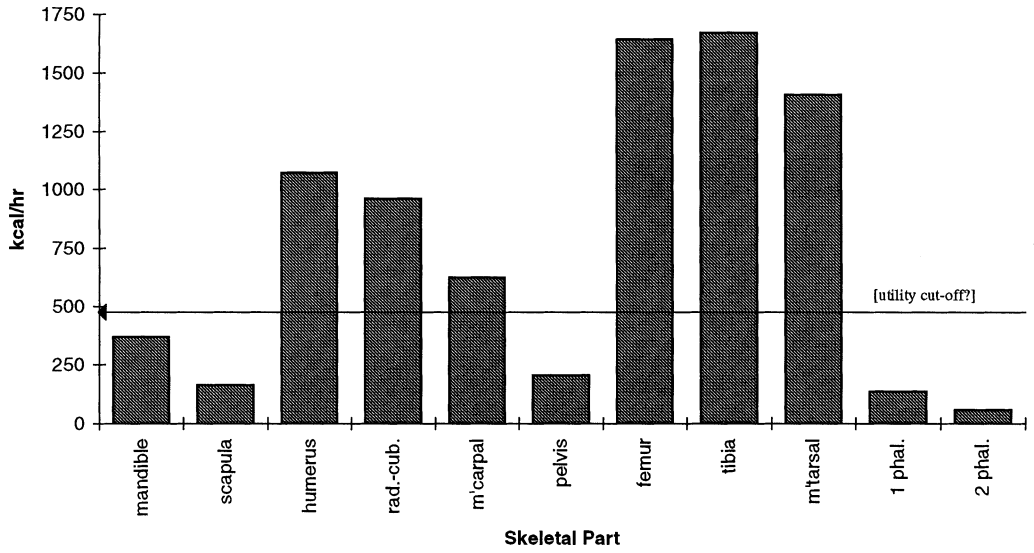

Fig. 2. A graph to show marrow extraction efficiencies from different caribou skeletal parts by the Nunamiut people and the processing threshold (values derived from Jones and Metcalfe 1988, table 3).

This is likely to apply much more to hunter/gatherer societies than to farming ones, where animals are more likely to be slaughtered where they are needed. There has been much discussion in the literature of differential skeletal part transport and the very many considerations that need to be taken into account when considering it (*e.g.* Binford 1978; Metcalfe and Jones 1988; O'Connell, Hawks and Blurton Jones 1990; Outram 2001b). Below, element transport choices will be modelled within the framework of an adaptation of Marginal Value Theorem (MVT).

Marginal Value Theorem (Charnov 1976) was originally created within the field of ecology to model an organism's use of different patches of resource, but it can easily be applied to human behaviour as well. Anyone with experience of collecting berries from wild hedgerows will understand this model very well. A berry collector will stop at a bush (or patch) and collect berries for a period of time. They are likely to leave that patch before all the berries on that bush are used up. This is because it gets harder and harder to find the berries on that bush and the rate of return gets lower and lower. At some point, one makes the judgement that it is probably better to go and find another bush. If there are lots of good bushes about, this point is likely to come sooner rather than later, but if bushes themselves are hard to find, one may stay longer at the present bush. MVT is all about predicting the optimal point at which one should move from one patch of resource to another.

A graphical solution for MVT can be seen in Fig. 3 (after Bettinger 1991, fig. 4.3). One can see that the energy acquired in the patch (expressed as a rate of return, usually energy/time) drops off as more time is spent at the patch. The dotted line represents the overall average rate of energy return of the environment, taking into account travel time, search time and handling time. If the overall return rate is higher than that from the present patch, then one would be better off leaving and looking for another patch. Where the straight overall return line touches the curved patch line is the optimum time to leave. The distance along the x-axis from the origin to the departure time is the optimal foraging time. The distance in the opposite direction along the x-axis from the origin, to the intersection of the axis by overall return line, represents the time that it is worth travelling to find other resources. The better the environment is, the steeper the overall line will be. It will touch the patch curve earlier and create a shorter optimal foraging time and a shorter acceptable travel time. If the environment is poorer, the reverse is true.

This model can easily be adapted to apply to the hunting of an animal and the exploitation of its carcass. A graphical solution for the adapted MVT can be seen in Fig. 4. This works in a very similar way. In this case the curved line represents a particular kill and the rate of return one can get from it as one field-butchers it for transport, selecting to take the highest return elements first (like picking the easiest to find berries). The dotted line represents the overall return for the environment in terms of finding, killing and transporting another animal. The same rules apply. The relationship between these two lines gives one the acceptable hunting time and optimal butchery/transport time. This time the model will dictate how many and which bones get transported back to the site. This model, however, also sees the introduction of the notion of total need. Infinite need is assumed within the standard MVT model, as the type of resource being dealt with is small and slowly accrued. Hunting can be different if a very large prey is captured. Total need might be met from the one carcass, if storage

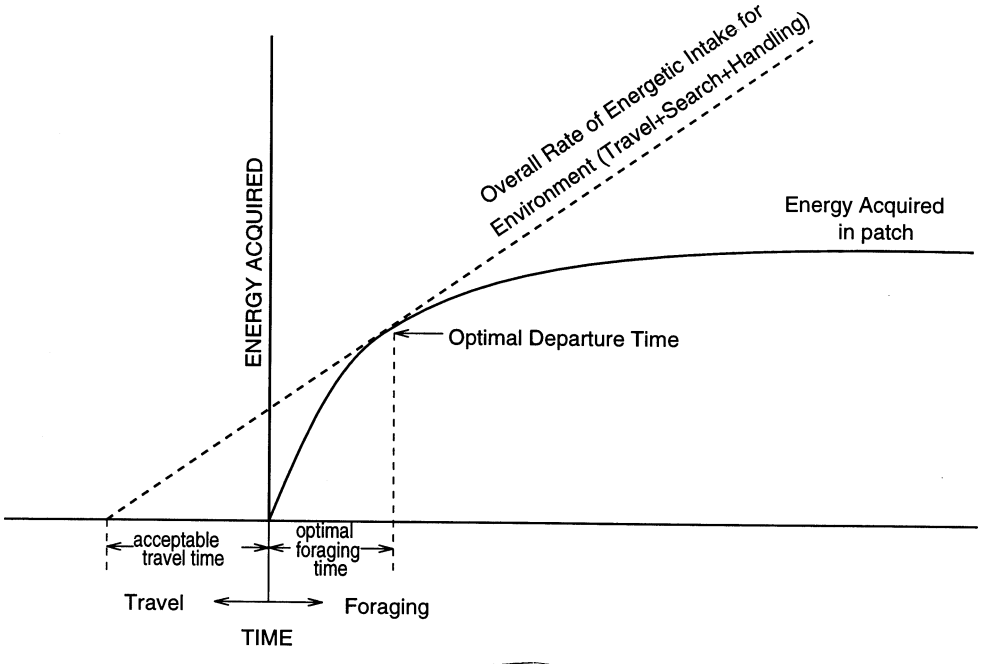

Fig. 3. A visual representation of Marginal Value Theorem (after Bettinger 1991, fig. 4.3)

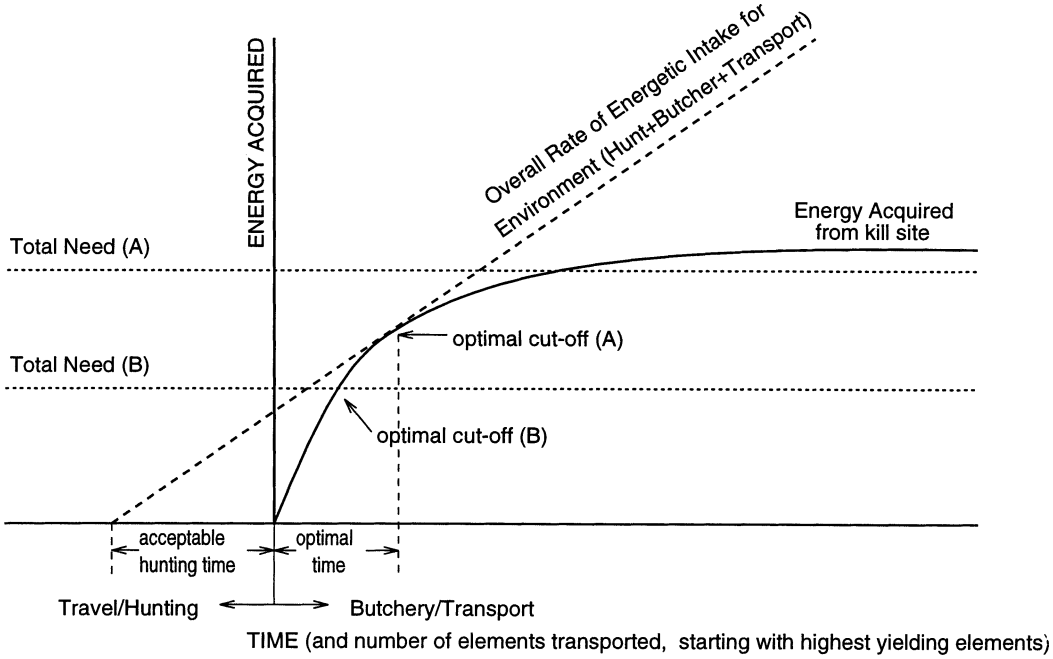

Fig. 4. A visual representation of Marginal Value Theorem as adapted to the consideration of hunters' element transport choices.

is not possible. If total need is reached before the intersection of the two lines, as in the case of total need B, the optimal cut-off will be earlier (cut-off point B), but if total need is higher (A) then normal rules apply.

Bettinger (1991, 108) suggested that element transport choices could be dictated by the theory of Diet Breadth. This is certainly true, but the adapted MVT model presented in Fig. 4 is possibly a more powerful tool because it effectively combines MVT with Diet Breadth. The model assumes that higher-ranking elements, in terms of energetic intake, will be exploited before lower ones. This assumption underlies the Diet Breadth Model (see below),

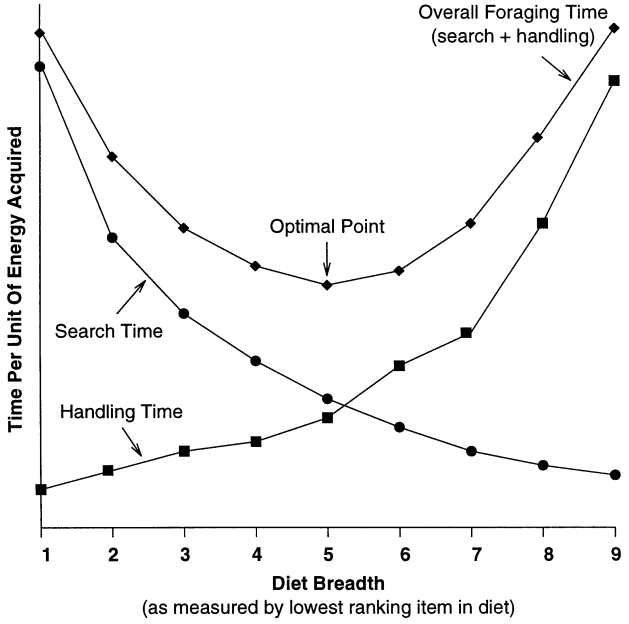
Overall Foraging Time
(search + handling)
Optimal Point
Search Time
Handling Time
Time Per Unit Of Energy Acquired
1 2 3 4 5 6 7 8 9
Diet Breadth
(as measured by lowest ranking item in diet)

Fig. 5. A visual representation of the Diet Breadth Model (after Bettinger 1991, fig. 4.1).

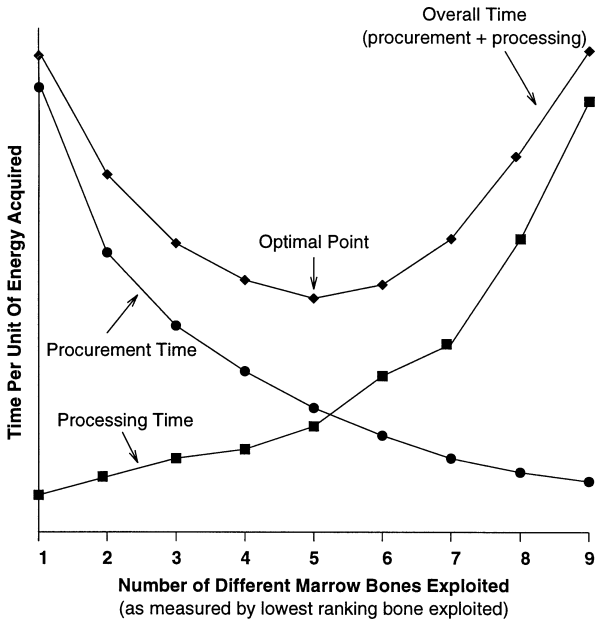
Overall Time
(procurement + processing)
Optimal Point
Procurement Time
Processing Time
Time Per Unit Of Energy Acquired
1 2 3 4 5 6 7 8 9
Number of Different Marrow Bones Exploited
(as measured by lowest ranking bone exploited)

Fig. 6. A visual representation of the Diet Breadth Model as adapted to the consideration of bone fat exploitation choices.

but is not normally present in MVT because the units being collected are normally assumed to be equal in value. In the adapted MVT model, both the rank order of exploitation and the optimal cut-off point are predicted.

Diet Breadth comes into its own in considering the choices people must make regarding which elements to process for their fat content. The Diet Breadth theory (MacArthur and Pianka 1966) can be seen graphically displayed in Fig. 5 (after Bettinger 1991, fig. 4.1). Dietary items are arranged along the x-axis in decreasing order of the food value of that item. This food value represents the energy yield divided by the handling time. A high-ranking item would be something like a large soft fruit, rich in sugar and easy to handle, whilst a low-ranking item might be something like a very small nut in a very hard shell. It would, in an ideal world, be best if one could just exploit the very high-ranking items, but this is where the search time comes in. The more items there are in one's diet, the greater the chance of encountering them whilst searching for food. Diet Breadth suggests the best balance between ease of handling and ease of searching.

In the graph (Fig. 5), it can be seen that as items are added to the diet (lower and lower ranking ones) the amount of handling time goes up, but at the same time the time needed to procure items goes down. The optimal number of items to include in the diet is then determined by where the two lines cross. Alternatively, if the two factors are combined into one line representing total time spent per unit of energy gained, the optimal point is where the time spent per unit of energy is lowest. If procurement is a problem (*i.e.* a low general yield from the environment), then this point will be reached later and more low-ranking items will be included. If procurement is not a problem then the optimal point will be reached early and only highly-ranked food items will be included in the diet.

This model can easily be adapted to consider bone fat exploitation more explicitly (see Fig. 6). This time the different fat-bearing bones are put in rank order according to processing efficiency. As suggested by the above discussion of bone fat exploitation patterns, this will not simply be a list of which bones contain the most fat. Highest ranking resources will be large, easily accessed marrow cavities, then smaller cavities will follow. One then has to move down to much less efficient grease processing and start with large appendicular ends, then smaller ones, then lower quality greasy elements from the axial skeleton and, perhaps, finally attempts to extract tiny amounts of fat from long bone shaft fragments. Clearly the more different types of bone fat resources one exploits, the easier it will be to procure the raw materials. The important question is how easy is it to procure fat resources. The harder it is to procure resources of fat (and one should perhaps be thinking about sources of fat holistically, rather than just bone fat), the later the cut-off point will be in terms of the exploitation of low-ranking bone fat resources.

From the above discussion of OFT models, it is clear to see how peoples' animal processing decisions, particularly for fat resources, can be very clearly linked to the environment around them. Optimal behaviour will change depending on just how marginal the environment

is. By applying OFT in this way, is one being 'environmentally determinist', as some would charge? Correctly used, OFT is not deterministic, but rather provides a measuring stick against which actual human behaviour can be compared (Foley 1985, 222; Bettinger 1991, 106). Without such a measuring stick it is very difficult to ascribe meaning to different human activities. How can one discuss the issue of marginality at all without reference to models that deal with resource availability within an environment and how people can best live in such an environment?

It is certainly true that optimal models do not determine human action, but having said that it can be argued that they can limit it. Higgs and Jarman (1975, 2) stated that "…ultimately all human culture and society is based upon and is only made possible by biological and economic viability…and however unfashionable the terms and ideas behind determinism may be, the very existence of natural laws presupposes a degree of determinism." This statement is extremely difficult to refute. People have to be able biologically to survive to have any sort of culture at all! Optimal models give us an idea of the best that can be done in a given environment, in terms of efficiency of resource exploitation. This is an upper limit that people may not necessarily adhere to. However, there is also a lower limit. People need so many calories and certain nutrients to survive. Almost by definition, in an economically marginal environment, these two limits will be close together and at the very edge of viability they are one and the same thing. One has to exploit efficiently all available resources to live. In a marginal environment, the chosen mode of economy WILL be heavily determined by that environment. As such, optimal models become highly relevant to understanding how that economy functions. Within this type of theoretical framework, the study of bone fat exploitation patterns could represent a powerful tool for assessing marginality and levels of dietary stress.

Methods

In order to understand the exploitation of bone fats, within a theoretical framework like the one presented above, one has to have some understanding of the rank order of elements, and portions of elements, in terms of their fat yield and processing efficiency. Lewis Binford (1978) revolutionised this field of study in two ways. Firstly, he created indices of fat utility (both for marrow and grease) for the different elements of two species, sheep and caribou. Secondly, he recorded efficiencies for grease processing by the Nunamiut using traditional techniques. Jones and Metcalfe (1988) further refined and discussed these data. Whilst many food utility indices and meat utility indices have been produced since 1978, many do not refer specifically to bone fats. Some exceptions are Brink and Dawe's (1989) work on bison, Blumenschine and Madrigal's (1993) work on East African ungulates and Outram and Rowley-Conwy's (1998) work on horses. Despite the relative lack of attention given to bone fat utility in the production of indices, we now have a fair range of information on the relative yields of bone fats from sample species with different stature and locomotor characteristics. It is also extremely useful that Brink's (1997) experimental work showed that fat content is very closely correlated to dry bone mass.

In order to take this line of enquiry further, one needs to be able to assess exactly which bone resources have been exploited for their fat content, and quantify this exploitation. The development of just such an analytical protocol, for application to archaeological bone assemblages, has been the subject of much of this author's recent work. Detailed explanations of this methodology can be found in Outram (1998; 2001a; 2002) and detailed discussion of example applications of the methodology can be found in Outram (1998; 1999; in press; forthcoming). What follows is a very brief summary and should be treated as such. The method relies upon the three strands of evidence, the fragmentation levels of different types of bone, the fracture patterns within the assemblage and the holistic consideration of a wide range of taphonomic indicators.

With regard to fragmentation level, one clearly needs to consider what types of bone have been broken up with regard to their potential value as a fat resource. The method used for recording the levels of fragmentation is as follows. All fragments are included, whether identifiable or not. Whilst identification to species and element may not be possible, such fragments still carry valuable information in the form of size, fracture patterns and bone type. It is possible to tell cancellous bone from diaphysis bone on even very small fragments and such information is very important in the context of a study like this. The entire assemblage is divided into size classes (by maximum dimension). The size classes used are <20mm, 20–30mm, 30–40mm, 40–50mm, 50–60mm, 60–80mm, 80–100mm, 100+mm and part and whole bones. Whole bones clearly have not been exploited for grease at all. Part bones include bones that are not whole, but represent whole units that could have been exploited for grease but were not broken up. Part bones include entire epiphyses and complete vertebral centra.

Quantification of the size classes is by number and mass. Whilst numerical data is collected, mass data tends to be more useful because it represents actual amounts of bone present. Clearly one unbroken large bone represents the same amount of potential fat as a similar element broken into many pieces, yet the latter would be represented by many hundreds on a numerical count. By mass, both would be suitably equal. Also, as previously mentioned, Brink (1997) concluded that dry bone mass was an accurate predictor of elements' bone grease utility.

For each size class, a distinction is made between whether the bone is cancellous or cortical in nature. For

large size classes, distinction is made between axial cancellous bone (other than ribs), ribs, articular bone from appendicular elements and diaphysis bone. This enables one to see, in terms of bone fat utility, which types of bone had been fragmented and to what level.

The study of fracture patterns is essential in establishing whether the fragmentation was the result of human agency and, if it was, to quantify the extent of deliberate comminution. When dynamically fractured in a fresh state, dense diaphysis bone creates a very distinctive fracture pattern. Such fractures are characterised by helical fracture lines radiating out from the point of impact. The fracture surface will form either an acute or obtuse angle to the cortical surface of the bone. This fracture surface will also tend to be smooth in texture (Johnson 1985; Morlan 1984; Outram 1998; 2001a; 2002). As bones dry out they develop small cracks that interfere with the fracture line, creating roughness or steps, hence affecting the fracture shape and surface texture. As bones lose their organic content they react differently to force. Loss of elasticity results in bones snapping in straight lines that tend to be perpendicular to the cortical surface. A largely mineralised bone will break with a straight, rough edge that is close to being at right-angles to the cortical surface.

The three criteria of fracture outline (shape), fracture angle (to cortical surface) and fracture texture (smooth or rough) can be used to characterise large assemblages of fragments in terms of the amount of deliberate fracturing of fresh bones versus levels of post-depositional breakage of dry bones (Villa and Mahieu 1991; Outram 1998; 2001a; 2002). An indexing system has been developed and tested experimentally by Outram (1998; 2002).

All diaphysis fragments of 30mm or more in length are studied for fracture type providing that preservation is good enough. For each of the three criteria, a score of 0, 1 or 2 is awarded. In broad terms, a score of 0 denotes that that criterion is consistent with fracture of a fresh bone, a score of one denotes a mixture of fresh and unfresh features (but with fresh still dominating) and 2 denotes that unfresh features are dominant. Much greater detail is available in Outram (2002). Shape, angle and roughness are all estimated by eye. This is essential to make assessments of large samples practical. Individual misjudgements will be irrelevant as the method is being employed to characterise the assemblage in general and sample sizes are large. The angle and outline characteristics are fairly easily defined, but assessment of roughness is more subjective and relies upon the analyst having a good mental template (like much zooarchaeological analysis) of the possible range.

When the scores are added together one ends up with a score from 0 to 6 for each fragment, called the Fracture Freshness Index (FFI) score (Outram 2001a; 2002). Scores of 0, 1 and 2 will represent bones broken in a relatively fresh state. Scores of 3, 4, 5 represent either bones that were broken when becoming fairly dry (unlikely to be for fat extraction) or bones which had some fresh fracture on them but were further fragmented when unfresh. A score of 6 represents a bone with no evidence of fresh fracture. The profile of scores and overall average for a sample can be displayed.

The FFI score is a very good indicator of the taphonomic history of the assemblage, but other indicators can be recorded that provide more detail and help to deal with potential problems of equifinality within the FFI. If one records whether or not a fragment has an example of an individual mineralised break it is possible to distinguish between bones that had fresh features, but then got broken when mineralized, and bones that showed no fresh or completely mineralized features, but were dry when broken (*i.e.* scores 4, 5, 6). Such completely mineralised breaks are easy to spot (on their own they would score 6). New breaks (caused by excavation or storage) can also be recorded, as the fracture surfaces will be an obviously different colour. Dynamic impact scars, created at the point of impact on a fresh bone, can also be recorded as evidence of deliberate fracture, much like bulbs of percussion on flints. If the bone cylinder was broken on an anvil, there may be a rebound scar due to the opposing force of the anvil (see Outram 2002, fig. 6.8).

Several other criteria are important for understanding the taphonomic history of the assemblage. Shaft fragments are also studied for evidence of animal gnawing and butchery (chops, cuts, polish and sawing). Numbers of burnt fragments are counted for the entire sample at the level of size class and bone type. Butchery can clearly add to the overall level of deliberate breakage, however, the breakage of bones for butchery purposes will be restricted to particular elements for a particular purpose, such as an alternative to disarticulating a difficult joint. There is also likely to be a difference between the fractures produced by chopping through meat and bone and those created by direct impact to the bone. It is essential that all indicators (fragmentation level, bone types, fracture patterns, gnawing, butchery and burning) are considered holistically to effect a successful interpretation and avoid pitfalls of equifinality.

Case Studies

Below, four case studies of the analysis of bone fat exploitation patterns are outlined. The details of the results for each case study will not be displayed as these have been or will be published at some length elsewhere (Outram 1998; 1999; in press; forthcoming). The purpose of this section is to present the principal points of interest emerging from the results of each study, so that they can be discussed with reference to the question of marginality. All case studies relate to economies that were highly dependent upon animal products and would have had little access to large quantities of dietary carbohydrate. As such, fat becomes a key resource.

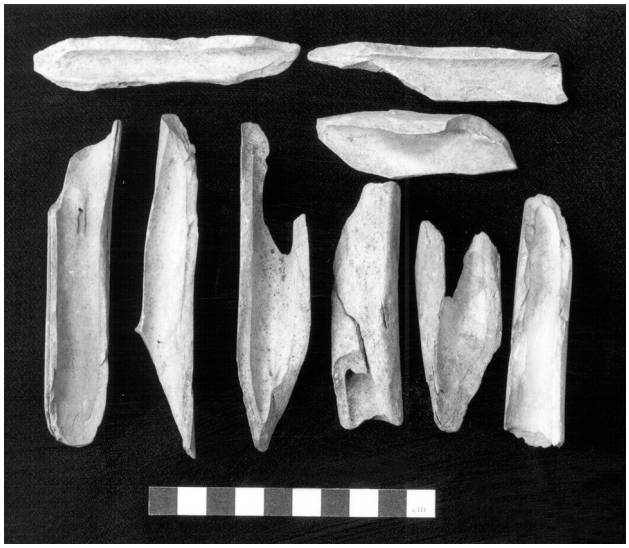

Fig. 7. Helically-fractured shaft splinters from the Norse settlement of Sandnes, Western Greenland, resulting from marrow extraction (scale in 1cm divisions).

Fig. 8. Heavily comminuted cancellous bone from the Norse settlement of Sandnes, Western Greenland, resulting from bone grease rendering (scale in 1cm divisions).

The first two case studies are set in Western Greenland (for detailed results see Outram 1999). Greenland, being physically difficult to reach, being at high latitude with a harsh climate and having difficult terrain with little suitable land for settlement, is perhaps a classic example of somewhere people think of as being marginal. The first study looked at two medieval Norse farmsteads called Sandnes (V51) and Niaquussat (V48). The Norse settled on Greenland in around AD 985 (Buckland *et al.* 1996) and operated a principally pastoral economy using cattle, sheep and goats. The diet was augmented with hunting of caribou, seals and wild birds, but fishing does not

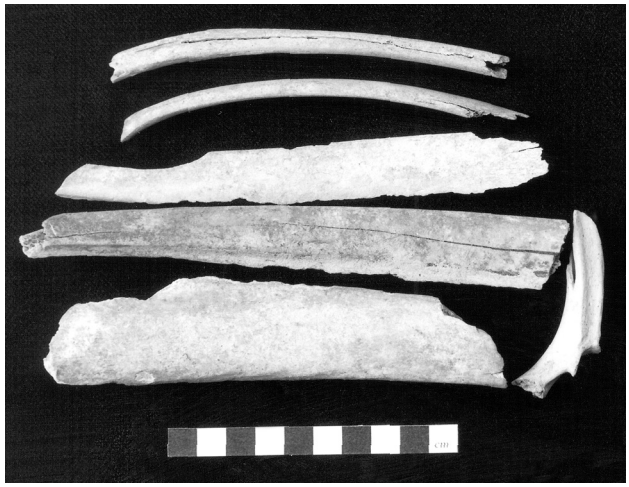

Fig. 9. Large, unprocessed rib fragments from the Norse settlement of Sandnes, Western Greenland (scale in 1cm divisions).

appear to have occurred much at all (for detailed discussion of economy see McGovern 1985; McGovern *et al.* 1996; Buckland *et al.* 1996). It is clear that life was very harsh indeed and one of the key limiting factors in the economy was the short growing season and limited availability of winter fodder for animals (McGovern 1985). With the climatic downturn at the start of the Little Ice Age, matters became worse and the Norse finally abandoned Greenland by the end of the 15th Century (Buckland *et al.* 1996).

Before the study by this author, Buckland *et al.* (1996) had already suggested from entomological evidence that the Norse were so stressed that they needed to render bones extensively for fat before depositing them in their middens. The study of the bone fracture and fragmentation patterns very much confirmed this. The land mammal bones had been very heavily processed indeed, at both farms, and the pattern was very clear and consistent. Almost all long bone shafts had been deliberately fractured to extract marrow (see Fig. 7) and almost all cancellous bone (axial and appendicular) had been comminuted into very small pieces for rendering (see Fig. 8). The only exceptions to this were the ribs (see Fig. 9), which are quite poor in terms of their grease value and contain largely red marrow (see above). Seal bone tended not to be fragmented. It was also clear that this pattern was almost entirely the result of deliberate human action, when considering all the taphonomic data holistically. The conclusion is that the processing of land mammal bone extends a very long way along the x-axis of a diet breadth model, which suggests that procurement of sufficient fat resources, and probably food in general, was very difficult, forcing the exploitation of very marginal resources of bone fat. There will be more discussion of seal below.

The other case study involved the examination of two

Paleo-Eskimo sites of the Saqqaq culture, which dates to approximately 2400–1000 BC (Grønnow 1988, 24). Qeqertasussuk (see Grønnow 1988; Böcher and Fredskild 1993) is a specialist seal hunting site and Itivnera (see Møhl 1972) is a specialist caribou hunting site. Just like on the Norse sites, the seal bone was not fragmented much at all. There was no evidence for the extraction of fat from them. At Itivnera, however, it was clear that the caribou bones were being processed for both grease and marrow. The patterning and method of processing seemed to closely follow that described by Binford (1978) for the Nunamiut. Long bone ends had been deliberately removed to leave shaft cylinders (Fig. 1). There was good evidence for the grease rendering, but certainly not in the quantities encountered at the Norse sites. The Saqqaq people left quite a few axial and appendicular cancellous portions unexploited, leading to the conclusion that they were less stressed and did not need to extend their diet breadth, in fat terms, as far as the Norse.

The third case study continues the theme by examining early medieval Norse settlements on Iceland at two farms called Hofstaðir and Sveigakot in Northern Iceland (see Outram in press for detailed study). Iceland has some similar features to Greenland, in environmental terms, but it does not have quite such a harsh climate and has better land availability, in other words is less marginal. The economy of Norse Iceland was also primarily pastoral and based upon cattle, sheep and goat with additional exploitation of pig and seals (Amorosi 1992; Tinsley forthcoming). Caribou were not available as a hunted resource (Amorosi 1992, 123), but on Iceland there was much fishing of both fresh water and sea species (Amorosi 1992; Byock 2001). The results of bone fracture and fragmentation analysis on these sites were in stark contrast to the Greenlandic results. It was immediately apparent that, whilst there was evidence for a certain amount of marrow extraction, there was no evidence at all for bone grease rendering. Fragmentation levels were very low and many bones survived whole. This suggests that the procurement of sufficient fat was not at all difficult within the Icelandic economy and that perhaps their economy was indeed less marginal than that on Greenland.

The final study relates to a Middle Neolithic site on the Swedish Island of Gotland called Ajvide (for detailed discussion of results see Outram forthcoming). The Middle Neolithic culture on the island is referred to as the 'Pitted Ware' culture, which spans from about 2700–2300 Cal. BC (Burenhult 1997). Gotland had seen the introduction of domestic animals including cattle, sheep and pigs in the Early Neolithic, but, during the Pitted Ware phase, it seems that the inhabitants of the island reverted to hunting and gathering, exploiting various species of seal, wild/feral pigs and fish (Rowley-Conwy and Storå 1997). Just like on Iceland, the bone fracture and fragmentation study uncovered very little evidence for systematic bone grease rendering, but it was clear that marrow was regularly exploited.

Discussion

It is clear from the above results that the patterns of bone fat exploitation were very different within the economies discussed. On a simple level, one can argue the following, with regard to relationship between bone fat exploitation and marginality. The Norse settlers and Paleo-Eskimos on Greenland shared a very similar environment, but the Norse economy was a cultural import from elsewhere that was not ideally adapted to the environment of Greenland. The result was significant stress upon the subsistence economy. The difficulty in procuring sufficient fat resources forced an increase in the diet breadth for bone fat exploitation. The clear evidence that this pattern of bone fat exploitation left is detectable archaeologically in a way that other evidence of stress might not be. The Saqqaq peoples clearly needed to exploit some bone grease, but it is equally clear that they were not in such a desperate situation, and probably had an economy that was far better adapted to the environment.

It appears that the Norse Greenlanders were doing their best to optimise returns from their chosen economy, but it also seems that they had culturally chosen to operate an economy that fell some way short of optimal for their environment. This underlines the point that OFT models do not determine actual behaviour. People do make cultural choices about how they will live within a given environment. However, if we do not have optimal models, or at least some set measuring stick, how would we know whether cultural decisions were divergent from practical adaptations to environment and of particular interest. Having said this, one must return to the point that life is only viable within certain limits. Cultural variability is only possible within the limits of optimal models at the top end and economic and biological viability at the other. On Greenland, the Norse did optimise their economy as far as they could without fundamentally changing it, but they did not truly optimise it to the environment. With the onset of climatic downturn, the limits of optimality and viability came closer together and their culturally chosen economy began to fall outside those limits. Environment demanded adaptation, but culture refused and the result was the abandonment of Greenland.

The Icelandic and Gotlandic examples show two economies that do not appear to have been so dietarily stressed. In both cases it appears that only marrow was being exploited, which is relatively highly ranked in a diet breadth model indicating that fat and food procurement in general was not that difficult. The four studies taken together show that the fracture and fragmentation methods can pick up the full range of different fat exploitation patterns and that these patterns, once identified, can be very useful in interpreting levels of economic stress.

Looking in greater detail at some of the complexities of these case studies, it is necessary to draw attention to some important interpretative issues, however. The first

and most important issue relates to the seasonal round within subsistence economies. It is extremely important to realise that economies are not static throughout the year and some times of year are likely to be far more stressed than others. It is highly likely that extreme patterns of bone fat exploitation will relate to particular seasonal dearths in food resources. This does not in any way negate the result for the settlement as a whole, however, as a subsistence economy is only as good as its weakest part. If one cannot weather the bad times through optimising resources (including use of storage where applicable), the good times are irrelevant.

In the case of the Greenlandic peoples, in both case studies the season of dearth was probably winter. In the Norse example there was food available from the pastoral economy during the summer, which would be nutritious and contain a good source of fat. The sealing appears to have taken place during spring (McGovern 1985, 101). Seals have vast amounts of fat in their blubber, so the bone fats would have been, in relative terms, much further down a diet breadth ranking list. This is no doubt why seal bones were not fragmented by either the Norse or Saqqaq peoples. The hunting of caribou would probably be best in Autumn, when they are at their fittest and domestic stock may well also have been slaughtered at this time, before over-wintering in the byres. This leaves winter, with only stored food available, including many bones from the autumn kills that could be rendered. In Iceland and at Ajvide there is not such a significant gap in the provisioning of food. On Iceland better environmental conditions could have led to the possibility of storing up more dairy products for winter, but, perhaps more importantly, the large amount of fishing carried out would have allowed stockfish to be kept for the winter period. At Ajvide there was also much fishing, but it was also clear that sealing was not so seasonally limited with different species being exploited through from autumn to the spring (Rowley-Conwy and Storå 1997). It can be seen that the seasonal availability of fat could be the critical factor in the study of these economies.

One final issue for discussion is a slight warning. Bone fats can be valued for industrial processes, for example waterproofing skins and treating bowstrings (Binford 1978, 24), tanning (Levin and Potapov 1964, 636) and lighting (Burch 1972, 362). As such, the consideration of bone fat exploitation as an indicator of dietary stress should not be taken out of the overall economic and archaeological context of the case study. Arguments about marginality and stress must use the full range of economic and environmental data holistically.

Conclusion

The study of patterns of bone fat exploitation in the archaeological record can be a powerful tool for understanding dietary stress within economically marginal environments. Our understanding of such environments can be enhanced by the use of appropriate models of optimal behaviour for such environments, when such models are correctly used as measuring sticks, not as determining laws. In considering marginal economies, special attention needs to be given to the identification of periods of seasonal stress. When using bone marrow and grease exploitation patterns as an indicator of dietary stress, this evidence should be fully integrated with other available economic and environmental data, and not treated in isolation.

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11. The Worst of Times, the Best of Times: Jackrabbit Hunting by Middle Holocene Human Foragers in the Bonneville Basin of Western North America

Dave N. Schmitt, David B. Madsen and Karen D. Lupo

*A number of paleoenvironmental and archaeological records from the northern Bonneville Basin, western U.S.A., indicate that middle Holocene desertification began about 8,300 radiocarbon years ago and persisted over the next several thousand years. A major aspect of this environmental shift in valley bottoms was the rather abrupt change from dense sagebrush and grassland habitats to more open xerophytic scrub communities. This dramatic biotic change prompted an overall decline in mammalian taxonomic diversity, marked population declines in small mammals adapted to cool and moist environs containing sagebrush and annual grasses, and increases in species well-adapted to open, low desert habitats, especially black-tailed jackrabbits (*Lepus californicus*). Using jackrabbit skeletal abundances from Camels Back Cave in concert with studies on small mammal ecology and human subsistence strategies, we propose that: 1) as the environment got "worse," the opportunity for taking jackrabbits* en masse *actually got better; 2) the pursuit of jackrabbits, most likely with communal techniques, contributed to increasing hunter-gatherer mobility, and; 3) Bonneville Basin foragers may have became more efficient hunters after this dramatic environmental shift than they were in the more favorable period preceding it.*

Introduction

As the papers in this volume clearly illustrate, 'marginal' areas are largely considered to represent the boundaries of the range of hominids in geographic terms. In addition to geographical marginality, harsh environmental contexts (*e.g.* extreme aridity or altitude) are also considered as marginal areas since they often afforded human foragers a limited and widely spaced suite of resources. Regardless of context, the archaeological record of these areas can provide key insights into human evolution and expansion, and zooarchaeological investigations can offer important information on variability in human adaptations.

This paper explores variability in an environmentally marginal context by examining changes in prehistoric human subsistence in the Bonneville Basin desert of western North America. We focus of the mammal remains from Camels Back Cave (Fig. 1) where block excavations recovered a series of mammal bone aggregates from deposits dating between approximately 12,000 and 500 radiocarbon years before the present (^{14}C BP). These assemblages include faunas deposited in stratigraphic horizons containing evidence of one or more visits by human foragers, while others are from layers with no evidence of human habitation and largely represent prey remains deposited by carnivorous birds and mammals. Among others, two aspects of the cave's archaeofaunal record are especially germane to the investigation of human and non-human animal ecology and behavioral variability in environmentally marginal contexts. First, they include a complete, stratified Holocene bone sequence from the southern Great Salt Lake Desert and analyses of small mammal abundances and diversity provide information on the timing and severity of paleoenvironmental changes in the region. Second, excavations in Stratum V recovered a very large jackrabbit (*Lepus californicus*) bone assemblage and comparisons with previous taphonomic studies and the cave's non-human bone aggregates indicate that most were deposited by human subsistence activities. Most importantly, the Stratum V jackrabbits were accumulated during a harsh climatic interval dated at approximately 6,600 ^{14}C BP and, at first glance, human foragers should have been anywhere else but in the inhospitable landscape surrounding Camels Back Cave.

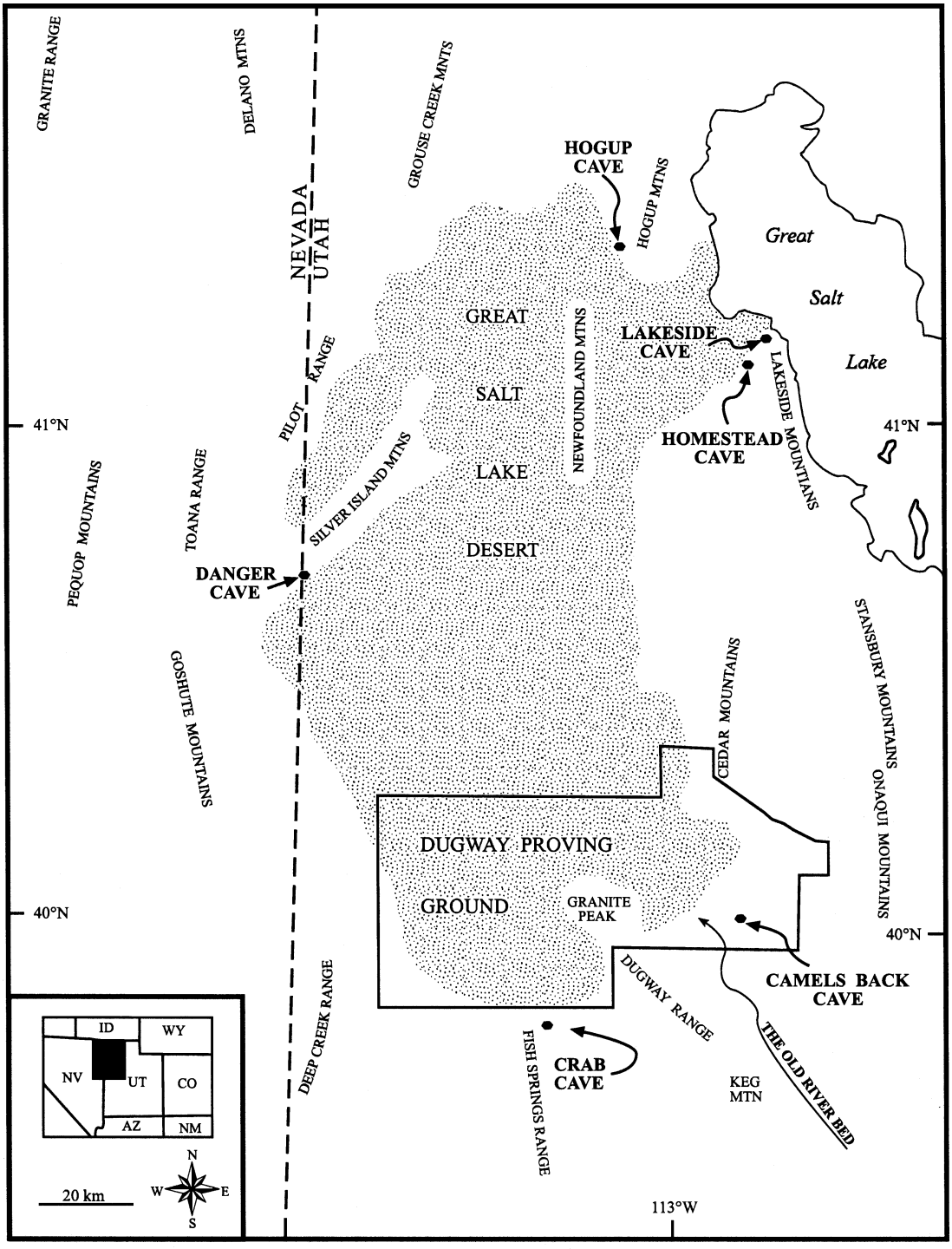

Fig. 1. Location of Camels Back Cave and other cave sites in the Bonneville Basin.

We begin this paper with a brief synopsis of the Bonneville Basin Paleoarchaic-Early Archaic archaeological record. An overview of Camels Back Cave is presented and we compare the cave's early and middle Holocene small mammals with specimens of similar age from the stratified deposits at Homestead Cave to examine regional paleoenvironments. We then present qualitative and quantitative data on the Stratum V *Lepus* bone assemblage and investigate how and why middle Holocene foragers exploited small game in this desolate and harsh context.

The Regional Archaeological Record

Except for a few cave sites, the Great Basin Paleoarchaic archaeological record (>11,000–8,000 ^{14}C BP) is comprised of open lithic scatters that usually lack associated buried deposits. Paleoarchaic (or Western Stemmed Tradition [*e.g.* Willig *et al.* 1988]) sites predominantly occur in pluvial lake basins on or near ancient beaches, stream-fed deltas, and/or marshes and indicate that wetlands were the focus of habitation (Beck and Jones 1997; Elston and Zeanah 2002; Jones *et al.* 2003; Willig *et al.* 1988). Sites of similar age in other parts of North America contain the remains of extinct megafauna and this 'big-game' hunting strategy was once thought to have been common in the Great Basin as well. To date, however, there remains no unequivocal association of cultural artifacts and extinct megafauna in the Paleoarchaic Great Basin; if fact, recent analyses the late Pleistocene archaeological record across North America indicate that megafaunal kill/processing sites are actually rare (Grayson and Meltzer 2002) and it appears that subsistence strategies were not centered on the pursuit of large game. Rather, faunal and human coprolite evidence from the early deposits in Danger and Hogup caves (Fig. 1) suggest that Great Basin diets largely included small mammals and wetland plant resources, especially chenopod seeds (Fry 1976; Grayson 1988).

While inferences on Paleoarchaic hunter-gatherer mobility remain somewhat speculative, it is reasonable to assume that mobility was highly variable. Some Great Basin groups practiced low residential mobility over restricted areas, some may have been highly sedentary but pursued distant food and toolstone resources by way of logistical forays over large areas while others shifted residence frequently over large areas. Food resources, especially those associated with shallow water, were probably only available on a seasonal basis and were present in limited quantities in the relatively small lake and river margin ecosystems present in most of the Great Basin. As a result, it is probable that most Paleoarchaic groups practiced high residential and territorial mobility in response to varying plant and animal abundances (*e.g.* Beck and Jones 1997; Elston and Zeanah 2002).

In the Bonneville Basin, a large number of Paleoarchaic sites have been identified along ancient shorelines and channel features in the Old River Bed delta north of Camels Back Cave (Arkush and Pitblado 2000; Madsen *et al*. 2000; Schmitt *et al*. 2002a). Geomorphic and geoarchaeological investigations indicate that the delta supported an extensive wetland between about 11,500–8,500 ^{14}C BP which covered some 750 km^2 across what is now the southern Great Salt Lake Desert (Fig. 1).

Paleoarchaic sites in the delta clearly fit within the Western Stemmed Tradition characterized by an adaptation to low elevation wetlands during the Pleistocene-Holocene transition, but mobility patterns of these early foragers appear to be different than foraging groups elsewhere in the Great Basin. Specifically, wetland ecosystems in isolated Great Basin valleys were small relative to those in the Old River Bed delta and foragers used a variety of widely-spaced toolstone sources, large flake and bifacial tools, and a relatively narrow diet breadth centered on resources in and adjacent to wetland habitats (*e.g.* Elston and Zeanah 2002; Huckleberry *et al.* 2001). It is likely that resources were often quickly depleted in these small wetland patches, necessitating frequent moves of relatively long distances between foraging localities. In the Old River Bed delta, however, bifacial tools are extremely small and often reworked and sources of toolstone are distant and limited in number, suggesting that movement was more restricted. Again, these deltaic wetlands were enormous relative to most other Great Basin wetland habitats, and while movement may have been as frequent, the distances involved were probably much shorter. Given the size of the delta, the large number of sites in remote contexts, the wealth of extensively reworked tools, it appears that local foragers rarely ventured out of these wetlands, especially during the latter part of the early Holocene (see Arkush and Pitblado 2000; Jones *et al.* 2003). While diet breadth may have been equally narrow, the shear size of the delta wetlands may have resulted in more restricted mobility patterns than those which characterize Paleoarchaic groups elsewhere in the region.

The end of the early Holocene is marked by increasingly warmer and drier conditions (see below), an overall decline in productivity, and changes in human adaptations (*e.g.* Madsen 1999). Bonneville Basin archaeological sites dating between 8,000–6,000 ^{14}C BP have been documented in a variety of settings, ranging from low elevation, lake-edge caves to high elevation encampments associated with montane resources (*e.g.* Aikens and Madsen 1986). Both the expansion into upland settings and increase in the number of sites on valley floors and margins clearly reflect an increase in mobility as regional desertification, at least in part, prompted frequent movements between patches of resources. Although most researchers acknowledge an increase in forager mobility and diet breadth at this time, some contend that human populations were expanding while others maintain that populations waned in response to increasingly arid climates (see discussions in Grayson 1993). Archaeological data from the Bonneville Basin suggest that populations were increasing during the early middle Holocene (*e.g.* Madsen 2002), but there has been little attempt to explain why human populations increased during an overall decline in biotic diversity and productivity. We believe that the content and context of early middle Holocene human occupations at Camels Back Cave provide some insights as to why Bonneville Basin foragers seem to have been prospering while environmental conditions were deteriorating.

Camels Back Cave

Camels Back Cave is a small north-facing portal (elevation 1380 m) in southern Camels Back Ridge in the Bonneville Basin of western Utah (Schmitt *et al*. 2002b; Schmitt and Madsen 2002). The ridge is a low, isolated limestone island adjacent the southeast margin of the Great Salt Lake Desert on lands administered by the U. S. Department of Defense, Dugway Proving Ground (Fig. 1). It is surrounded by alkali flats and low dunes and the region currently supports a xeric scrub community containing scattered greasewood (*Sarcobatus vermiculatus*), four-winged saltbush (*Atriplex canescens*), pickleweed (*Allenrolfea* sp.), and salt grass (*Distichlis* sp.). The nearest source of permanent water is at Simpson Springs some 15 km to the southeast of the cave. Between 1996–1998 we stratigraphically excavated a contiguous 2 x 4 m block of deposits down to Pleistocene Lake Bonneville gravels resting on the bottom of the cave. A total of 33 stratigraphic horizons was identified, 17 of which contained evidence of human occupations spanning the last 7,500 ^{14}C years. The majority of the cultural horizons in Camels Back Cave contained small artifact assemblages associated with one or more simple, unprepared hearths which suggest that most occupations were very brief (Schmitt and Madsen 2002). Twenty-six sequential ^{14}C dates from 18 stratigraphic units suggest there has been little or no mixing of deposits of differing ages and the results of radiocarbon assays provide accurate proxies for the age of materials within each unit.

Paleoenvironments

The rich floral and faunal records from excavations in Homestead Cave in the Lakeside Mountains (Fig. 1) provide exceptional information on late Pleistocene and Holocene climates and biotic communities in the Bonneville Basin (Madsen 2000; Madsen *et al.* 2001; see also Madsen 1999). As part of the Homestead analyses, Grayson (1998, 2000a, 2000b) examined changes in the types and abundances of small mammals and discovered that northerly parts of the Great Basin during the early Holocene were cool and moist, and the onset of warmer and drier middle Holocene climates is marked by extinctions or dramatic declines of montane mammals in low elevation contexts. This marked decrease in taxa adapted to cool and moist habitats occurred about 8,300 ^{14}C BP and is coupled with a significant decline in taxonomic diversity (see especially Grayson 1998). These changes in the Homestead Cave fauna correspond with regional vegetation records (Rhode 2000; Wigand and Rhode 2002) which suggest that moist sagebrush-grassland habitats deteriorated and desert scrub communities began to expand just before 8,000 ^{14}C BP.

In a recent paper, we (Schmitt *et al.* 2002b) examined the changing proportions of seven small mammals adapted to cool and moist settings from the early deposits in Camels Back Cave for comparison with the Homestead faunal record. Three of these species, including the bushy-tailed woodrat (*Neotoma cinerea*) and yellow-bellied marmot (*Marmota flaviventris*), predominantly occupy cool montane settings in the modern Great Basin (*e.g.* Grayson 1993) and four, including the pygmy rabbit (*Brachylagus idahoensis*), sage vole (*Lagurus curtatus*), and western harvest mouse (*Reithrodontomys megalotis*), largely inhabit moist habitats containing a thick grass understory and/or dense stands of sagebrush (*e.g.* Katzner and Parker 1997; Webster and Jones 1982). Our comparative analysis found the Camels Back faunas to show similarly conspicuous declines or extinctions of taxa adapted to cool and moist contexts about 8,300 ^{14}C BP (Schmitt *et al*. 2002b, Fig. 2), thereby providing further testimony to the severity and rather rapid onset of middle Holocene desertification in the region.

To further investigate changes in the prehistoric biotic community surrounding Camels Back Ridge, we examined changes in the cave's leporid abundances since jackrabbits and cottontails (*Sylvilagus* sp.) tend to favor different habitat types. Specifically, cottontails most often occur in areas containing a dense cover of perennial shrubs which is used to hide from predators (*e.g.* Chapman 1975). Conversely, jackrabbits rely on their ability to run (rather than hide) from predators and are particularly common to open desert habitats (Best 1996; Dunn *et al.* 1982); as we discuss below, prehistoric foragers may have taken advantage of this behavior by mass collecting jackrabbits in communal drives. We plotted the ratio of *Sylvilagus* to *Sylvilagus* and *Lepus* through time at Camels Back Cave (Schmitt *et al.* 2002b, Fig. 3) and found *Sylvilagus* to dominate the leporid fauna until approximately 8,500 ^{14}C BP. By about 8,000 ^{14}C BP, *Lepus* 'replace' *Sylvilagus* and comprise over 95 percent of the identified leporid fauna in each stratigraphic aggregate spanning the remainder of the Holocene. The changing proportions of identified *Lepus* bones through time compared to all other mammals in Camels Back Cave (Fig. 2) show a similar pattern. Jackrabbit relative abundances increase significantly about 7,700 ^{14}C BP and remain markedly abundant until 6,200 ^{14}C BP, and decline yet remain common throughout the remainder of the Holocene. The changing proportions of these mammals at Camels Back Cave are similar to those at Danger Cave where *Lepus* abundances rise significantly near the onset of the middle Holocene and comprise 85 percent of the identified mammals in deposits dating between 7,500–6,500 ^{14}C BP (Grayson 1988, 33–34).

Bonneville Basin biotic records suggest that middle Holocene desertification began about 8,300 ^{14}C BP and increasingly arid climates prompted the expansion of open xeric scrub communities. Warm and dry conditions persisted across the region for the next several thousand years and *Lepus* skeletal abundances in Camels Back Cave suggest that local jackrabbit populations flourished

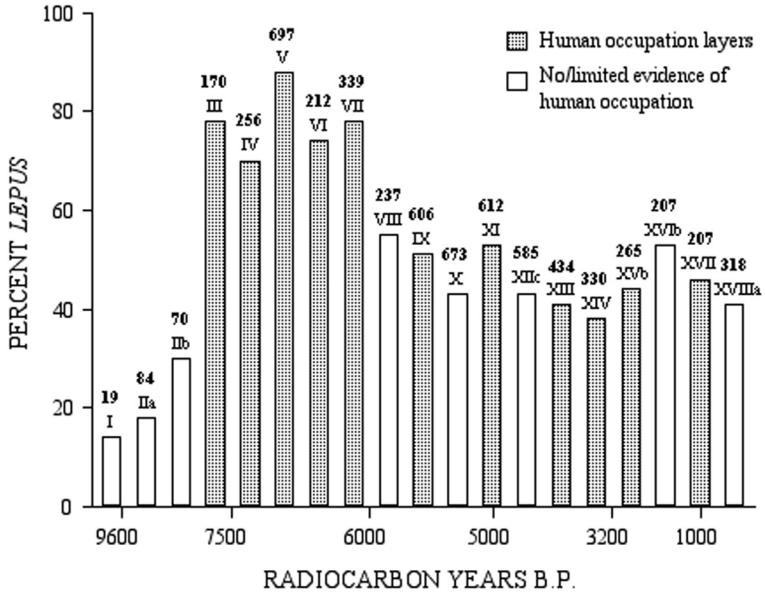

Fig. 2. The changing relative abundance of Lepus *compared to all other identified mammals through time at Camels Back Cave. Roman numbers above the bars identify the stratigraphic aggregates and the bold numbers provide the total number of identified* Lepus *specimens (NISP) in each stratum.*

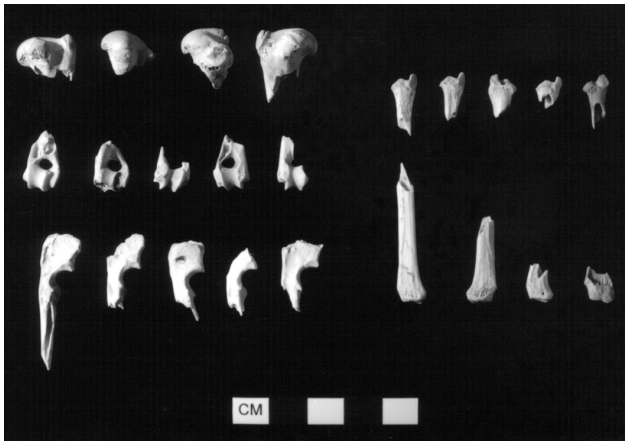

Fig. 3. Examples of partially digested Lepus *limb bone fragments from non-cultural horizons in Camels Back Cave: proximal humeri (upper left); distal humeri (left, center); proximal ulnae (lower left); proximal radii (upper right); distal radii (lower right).*

throughout most of this climatic interval. As *Lepus* populations escalated, it is reasonable to infer that this brought forth a corresponding increase in avian and terrestrial animals that commonly pursue *Lepus* for food. Many of these predators frequent sheltered contexts and it is likely that the high abundance of *Lepus* reflects an increase in some predator populations and their use of local caves. Humans were among these predators and appear to have been a significant accumulator of *Lepus* bones during this interval at Camels Back Cave, especially during the occupations of Stratum V.

The Stratum V *Lepus*

Stratum V is an artifact-bearing horizon measuring approximately 20 cm in thickness. It contains fire hearths, a few ground and battered stones, and modest assemblages of flaked stone tools and debitage. The most striking feature of this stratum is the recovery of 697 identifiable *Lepus* bones which represent the largest *Lepus* bone aggregate collected from the cave (see Fig. 2). Based on the numbers and distribution of hearths and associated radiocarbon dates, high *Lepus* bone densities appear to be associated with five or six occupations that occurred between about 7,100 and 6,400 ^{14}C BP. Excavations across the top of Stratum V encountered what we identified as a 'living surface' (Schmitt and Madsen 2002, 260–67) that manifests a literal jackrabbit bone-bed containing hundreds of *Lepus* bones. *Lepus* bone densities collected from this thin (2–3 cm) surface exceed 100 specimens per m^2 in some areas and appear to represent the last of a series of human occupations that centered on the procurement of large numbers of hares.

Taphonomic Comparisons

Because caves provide habitation sites for a variety of non-human predators and collectors, we were concerned with identifying the mechanisms responsible for jackrabbit bone accumulations throughout the cave deposits,

including Stratum V. As such, we conducted a series of taphonomic comparisons with reported canid- and raptor-produced leporid bone assemblages (*e.g.* Hockett 1991, 1993, 1996; Schmitt 1995; Schmitt and Juell 1994; Stahl 1996), and we compared specimens from the cave's cultural deposits against bones collected from strata containing no evidence of human habitation. Although the results of these detailed comparisons are presented elsewhere (Schmitt and Madsen 2002), analyses of skeletal completeness and part representation warrant discussion here since they provide insights to carcass acquisition and processing strategies by the occupants of Stratum V. We acknowledge that the taphonomic histories of some specimens remain ambiguous, including undetected human food refuse in horizons containing little or no evidence of human habitation. Regardless, we believe that our detailed scrutiny of large numbers of specimens from distinct stratigraphic units offers useful aggregates for distinguishing and comparing human versus non-human small-mammal bone accumulations in the cave.

First, macroscopic observations of *Lepus* remains from strata containing no evidence of human occupation found most to be highly fragmentary and exhibit corrosive attrition that compares favorably with bones deposited in coyote (*Canis latrans*) scats (Schmitt and Juell 1994; Schmitt and Lupo 1995). For example, identified portions of the mandible and scapula are predominantly small fragments that display evidence of partial digestion in the form of extensive polish, including the rounding of fracture surfaces, corrosive pitting, and/or staining. Anterior segments of the mandible are most abundant and include small, pitted horizontal ramus segments and large numbers of stained and highly polished diastema fragments. *Lepus* scapulae are largely represented by partially corroded glenoid fragments retaining portions of the neck or, in a few cases, part of the distal blade. In most instances attached neck remnants tend to be relatively small (< 1.5 cm in length) and often exhibit rounded and polished fracture surfaces.

Although some partially digested *Lepus* mandible fragments, scapulae, and other bones were identified in Stratum V, the assemblage contains large numbers of complete or nearly complete elements that are markedly different than the non-cultural aggregates. Mandible breakage, when present, is usually evident only along fragile, low density posterior margins (see Pavao and Stahl 1999) while anterior segments, including complete alveoli, remain intact. Two types of damage patterns tend to be common on the Stratum V scapulae: feathered breakage of the proximal blade and/or intact blades with broken necks. Since *Lepus* scapula blades are thin, fragile segments and breakage along proximal margins is often superficial, it is likely that many of the scapulae were deposited as complete elements. Conversely, some intact or nearly intact scapula blades with broken necks may represent human damage associated with disarticulation of the arm.

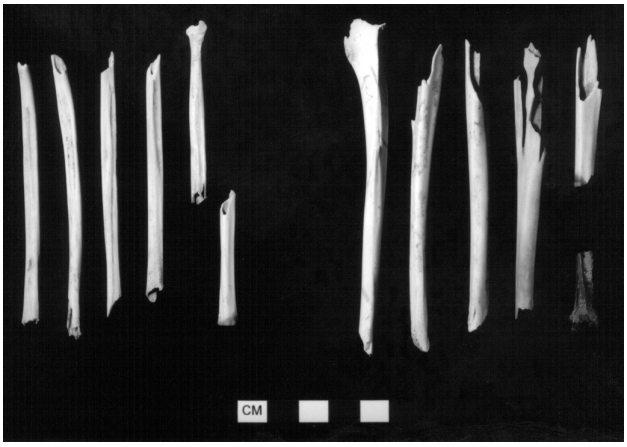

Fig. 4. Examples of Lepus *radius (left) and tibia (right) large shaft segments and diaphysis cylinders deposited by human foragers in Stratum V. The distal tibia with partial shaft (lower right) is completely carbonized.*

Lepus limb bones from the cave's non-cultural strata are also highly fragmentary and consist predominantly of articular ends retaining small portions of the shaft (Fig. 3). Extensive digestive polish is often evident on jagged fracture surfaces and some articular ends and shaft remnants display tooth punctures and/or crushing. In stark contrast, a large number of the Stratum V *Lepus* limb bones are represented by large shaft segments (Fig. 4) and include 103 diaphysis cylinders. *Lepus* limb bone cylinders (especially tibiae) have been reported in a variety of Great Basin sites spanning most of the Holocene (*e.g.* Drews and Schmitt 1986; Hockett 1993, 1994; Schmitt 1990; Schmitt and Lupo 1995) and cultural contexts in other parts of the world (*e.g.* Hockett and Haws 2002 and references therein). Neotaphonomic studies demonstrate that non-human predators and collectors rarely produce this type of damage (Hockett 1991, 1993; Schmitt 1995) and ethnoarchaeological observations have documented the production of small mammal diaphysis cylinders during carcass disarticulation and consumption by contemporary hunter-gatherers (*e.g.* Jones 1984).

A second and rather salient feature of the Stratum V jackrabbit fauna is the differential representation of skeletal parts which, again, is different than non-cultural bone aggregates. Figure 5 presents the numbers of identified primary paired *Lepus* body parts (NISP) and minimum numbers of elements (MNE) from strata containing no evidence of human occupation, and NISP and MNE tallies of specimens identified as human subsistence refuse in Stratum V. Although relative body part frequencies in the non-cultural aggregates are somewhat variable, they tend to contain large proportions of humeri and femora. Conversely, the Stratum V *Lepus* fauna contain large numbers of mandibles, scapulae, tibiae, and

Element	XVIIIa NISP	XVIIIa MNE	XIIc NISP	XIIc MNE	X NISP	X MNE	V surface NISP	V surface MNE	V all NISP	V all MNE
Mandible	27	10	57	20	51	17	29	22	86	57
Scapula	13	12	24	18	26	24	36	31	66	56
Humerus	33	23	44	25	60	36	16	11	38	25
Radius	10	5	21	12	27	15	23	20	60	47
Prox. Ulna	12	10	19	16	27	26	8	6	15	12
Innominate	8	7	13	7	37	18	5	4	18	15
Femur	32	20	63	39	85	44	9	5	32	17
Tibia	15	11	57	29	44	21	34	20	81	49
Calcaneus	7	7	37	34	21	19	0	0	8	8
Totals	157	105	335	200	378	220	160	119	404	286

Fig. 5. Numbers of identified Lepus *primary paired body parts (NISP) and minimum numbers of elements (MNE) from collections in non-cultural strata XVIIIa, XIIc, and X, and Stratum V, Camels Back Cave. The Statum V tallies exclude specimens that display evidence of partial digestion or other modification by non-human predators.*

	XVIIIa	XIIc	X
XIIc	0.148	–	–
X	0.079	0.133	–
V surface	**0.235**	**0.330**	**0.287**
V all	**0.184**	**0.270**	**0.227**

$p > 0.01$; $\mathbf{p < 0.01}$

Fig. 6. Kolmogorov-Smirnov values (D) for comparisons between Lepus *primary paired body part frequencies (MNE) in selected non-cultural strata and Stratum V (see Fig. 5).*

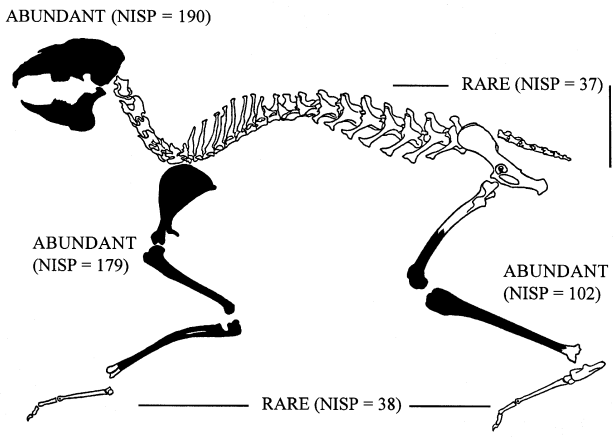

Fig. 7. Generalized profile of Lepus *skeletal part abundances recovered from Stratum V. All NISP counts exclude specimens that display evidence of partial digestion by non-human predators.*

radii. Statistical comparisons of element representation between the non-cultural assemblages result in positive correlations (Fig. 6), while relative body part frequencies in Stratum V are significantly different than those accumulated by non-human predators and collectors.

After omitting recognizable non-human bone accumulations from the Stratum V assemblages, minimum number of individual counts for the Stratum V fill identified 21 individual jackrabbits and the remains of at least 20 additional individuals were collected from excavations across the Stratum V surface. Since less than 20 percent of the deposits were exposed in our modest block excavations and only a sample (67 percent) of the Stratum V fauna were analyzed, it is reasonable to assume that the upper living surface alone contains the remains of some 100 individuals deposited by human foragers.

Human Subsistence Strategies

To further explore differential part representation in Stratum V, Fig. 7 presents a generalized plot of *Lepus* skeletal abundances by body segment. Again, this profile shows that bones from the head, shoulder/arm, and lower leg are most abundant, but it also illustrates the scarcity of vertebrae, innominates, proximal femora, and feet. We believe that both overall jackrabbit abundances and marked differences in part representation – notably the paucity of meaty, high utility portions of the back, rump, and upper thigh – are a reflection of human acquisition

strategies and differential part processing and transport. Specifically, the inhabitants of this horizon extensively pursued jackrabbits and it appears that they were taken in large numbers, most likely during a series of mass collecting events. The Stratum V jackrabbits were collected from a nearby context, possibly with the use of nets, and the upper living surface appears to represent the last episode(s) of about four similar mass collecting events. Both regional ethnographic documentation (Shaffer and Gardner 1995 and references therein) and the archaeological recovery of nets from early and middle Holocene deposits at Hogup Cave (Aikens 1970) offer evidence for the occurrence, indeed the importance, of rabbit drives in the prehistoric Great Basin. Whether or not nets were used by the Stratum V occupants remains unknown, but it does appear that *Lepus* were at times taken in large numbers and it is likely that they were hunted by small groups or families that employed some sort of communal technique.

Once large numbers of animals were acquired, carcasses were transported to the cave where meat on skulls and shoulders and both the meat and snacks of marrow associated with most appendages were often consumed. The paucity of proximal femora, innominates, and thoracic and lumbar vertebrae suggest that these high utility portions were most often transported from the cave for subsequent processing at another location, most likely a base camp or village site. The lack of metapodials, carpals/tarsals, and phalanges suggests that feet may have been simply removed and discarded or, perhaps, these body segments were removed and consumed at a field processing site (see Schmidt 1999). Complete carcasses appear to have been processed and consumed on some occasions, but the low frequencies of elements associated with the back, rump, and feet are especially consequential when considering the large numbers of these bones in a single *Lepus* skeleton. Even if nets were not used and individual hares were taken with traps or projectiles, skeletal abundances and part representation strongly suggest that local *Lepus* abundances were high and hunters often amassed surpluses of meat for transport to other locations.

A final and important consideration is site context. Camels Back Cave is a small chamber in a harsh and remote low desert setting that offered regional foragers little water and limited food resources. Although habitation of Stratum V was more intensive than some other visits to the cave, the modest artifact assemblages and undisturbed nature of the deposits indicate that these visits were nonetheless brief. It is doubtful that Camels Back Cave served as a habitation site where large numbers of complete *Lepus* carcasses were processed and consumed by a large group(s). Rather, site setting and the paucity of associated artifacts suggest that Stratum V manifests a series of brief stays (some probably spanning only a few days) by small groups of mobile foragers (Schmitt and Madsen 2002). Moreover, site context and skeletal abundances suggest that local jackrabbit hunting may have been the primary reason for a number of these stays.

Discussion and Summary

Shifts in subsistence patterns at the end of the early Holocene are commonly thought to be associated with a dramatic decrease in productivity, a decrease in the availability of high ranked resources, and a reduction in human forager populations. Yet there is no evidence of a major population decline, at least in the Bonneville Basin (see Grayson 1993, 246–248). Indeed, based on the number of sites occupied, human foraging populations appear to have increased after 8,000 years ago. While some of this may be due to an increase in mobility, there appears to have been a relative gradual and consistent increase in population density throughout the Holocene (Madsen 2002). This seems counter intuitive; that as conditions get worse, people do better. How could this be so?

First of all, there is little or no evidence that regional Paleoarchaic-Early Archaic foragers were focused on high ranked, high return large mammal resources. Rather, they appear to have been focused on valley bottom marsh resources that generally have low-to-medium return rates. What makes such marsh resources attractive is that there are many different kinds and they are closely spaced and available throughout much of the year (*e.g.* Madsen 2002). We propose that hunting in the vast deltaic marshes north of Camels Back Ridge focused predominantly on small game rather than large game, including waterfowl and fish (see Eiselt 1997), and regional shifts from late Pleistocene-early Holocene hunting patterns to those of the middle Holocene probably involved a shift in the *kinds* of small game that were hunted.

Again, a major aspect of the environmental shift after 8,300 BP is the change from a relatively thick vegetative cover on valley bottoms to a more open cover of xeric shrubs. Since jackrabbits prefer open habitats and react to threats by darting swiftly in and about open brush communities in order to elude predators, they are susceptible to collection through communal drives (*e.g.* Shaffer and Gardner 1995; Szuter 1991). Mass collecting of small animals can produced caloric return rates out of proportion to animal body size (Madsen and Schmitt 1998) and, as Simms (1987) notes, estimated return rates for the mass collecting of jackrabbits approach, and sometimes exceed, those for the encounter hunting of deer and mountain sheep, and are markedly higher than those for the encounter hunting of other small game.

This is not to say that local foragers ignored large game while hunting hares. Quite the contrary. Research has shown a positive relationship between animal body size and caloric return rate in the hunting of individual animals, and foraging theory predicts that a large, high-ranked prey item will be taken whenever it is encountered

(*e.g.* Broughton 1994; Simms 1987). However, the negative effects of drought on artiodactyl populations (*e.g.* Douglas and Leslie 1986) and the paucity of artiodactyl remains in the cave's middle Holocene deposits (*e.g.* Stratum V NISP = 10) suggest that local populations were limited during this harsh climatic interval and high search costs likely precluded their pursuit. Moreover, the flourishing populations of hares represented a seasonably abundant and predictable food resource, and the returns from mass collecting these animals may have outweighed the pursuit of large game even on the rare occasions they were available.

Overall, the data suggest that as the Bonneville Basin environment got 'worse' after 8,000 ^{14}C BP, the opportunity for hunting jackrabbits actually got better – at least in some contexts during certain times of the year – and human foragers may have become more efficient hunters after this dramatic environmental shift than they were prior to it. Mass collecting may have even contributed to increasing mobility, as prey populations in any one area would have been reduced after a number of communal hunts. The mass collecting of jackrabbits during early middle Holocene occupations at Camels Back Cave provides some of the best evidence for this counter intuitive explanation of why Bonneville Basin human populations seem to have been increasing while environmental conditions were degrading.

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12. A Zooarchaeological Perspective on the Origins of Vertical Transhumant Pastoralism and the Colonization of Marginal Habitats in Temperate Southeastern Europe

Elizabeth R. Arnold and Haskel J. Greenfield

The temporal origins of transhumant pastoralism in temperate southeastern Europe have long been debated within the archaeological literature. Previous hypotheses each propose a different point in time when transhumance would appear, ranging from the appearance of the earliest domestic animals (advent of the Early Neolithic), to the appearance of secondary product exploitation (advent of the Post Neolithic = Eneolithic and later periods), and to the appearance of complex societies (advent of the Iron Age). This investigation seeks to test for the appearance of transhumance in the northern half of the Balkan Peninsula.

In this essay, we propose to test each of these hypotheses utilizing zooarchaeological data from the central Balkans. Data were collected from over a dozen archaeological assemblages from the region extending from the Early Neolithic to the Early Iron Age. It is proposed that the advent of transhumant pastoralism should be visible by the appearance of complementary culling patterns between highland and lowland sites in the region.

*The primary technique used to investigate these hypotheses involves the creation of harvest profiles from mandibular tooth wear and eruption data of remains from three domestic animal taxa (*Ovis/Capra*,* Bos taurus *and* Sus scrofa*). Cementum analysis of modern and archaeological mandibular* Ovis aries *and* Capra hircus *teeth was a secondary technique that provided supplementary seasonality of culling estimates.*

*Several overriding methodological issues, including sample size and taphonomic problems, hampered this research. As a result, it was not possible to provide any strong support for any of the above hypotheses. There are hints in the zooarchaeological data, though, that transhumant pastoralism appeared at the advent of the Post Neolithic (*c. *3000 BC). By the Early Iron Age (*c. *1000 BC), the evidence for transhumance is clearer. This is supported by a variety of other data sources. Archaeological evidence indicates that significant colonization of the highlands began after the end of the Neolithic.*

Introduction

The colonization of agriculturally marginal zones in the highlands of Europe has long been thought to be part of the long and slow process begun by Neolithic agriculturalists. In recent years, however, it has become apparent that there is a different pattern of colonization between temperate and Mediterranean Europe. There is evidence for the colonization of the highlands by at least seasonal settlements along the Mediterranean littoral from the earliest agricultural periods (Barker 1985; Maggi *et al*. 1990). In contrast, the pattern in temperate Europe is dramatically different. Along its southern periphery (*e.g.* the Northern Balkans), there is no evidence of colonization of the highlands until the beginning of the Post Neolithic (Eneolithic and Bronze Age). It is only at this point in time that settlements, rather than specialized resource extraction stations, are established. Whether these are seasonal or permanent remains to be determined. In this essay, we propose to test the hypothesis that the colonization of the agriculturally marginal highlands of temperate Europe coincided with the advent of vertical transhumant pastoralism in the region.

Transhumant pastoralism is an economic activity involving the seasonal movement of domestic herds between altitudinally differentiated and complementary pastures (Geddes 1983). Historically, it has been a significant part of the economy in southern Europe, both along the Mediterranean littoral and in the temperate region to the

immediate north (*e.g.* the Northern Balkans). Archaeologically, many researchers (Halstead 1981, 1996; Geddes 1983; Greenfield 1986) agree that it was also an important element of the economy in prehistoric times (Sherratt 1980, 1982, 1983; Harding 2000). When it appeared, and why, becomes therefore an important issue (Greenfield 1988, 1991, 1999, 2001a). Transhumance is a widespread adaptation to the exploitation of marginal environments. It has long been and is still practiced throughout the temperate zone of southeastern Europe (Bartosiewicz and Greenfield 1999). Even though pastoralism is still an important form of land use in this and many other parts of the world, little research has been conducted on its origins using archaeological methods and data.

In the Mediterranean littoral (*e.g.* the Southern Balkans), the advantages of transhumant pastoralism are more obvious as high summer temperatures and lack of sufficient water and pasturage creates a marginal environment in the lowlands. In response, herds are moved to the highland pastures in the summer. In the temperate environment north of the climatic divide (*e.g.* the Northern Balkans), this marginal summer lowland environment does not occur. Temperatures are not as extreme and sufficient water and graze are available year-round in most low- and mid-altitude pastures. Additionally, microenvironments exist, such as marshes, streams, hills and plains, to allow for stock to be safely herded throughout the year in the lowlands. As a result, there are fewer incentives for pastoralists from low- and mid-altitude settlements in temperate regions to practice transhumance. However, the problems arise when agri-pastoralists move to the more marginal highlands. In this environment, it is difficult if not impossible to maintain herds without extensive foddering. Little evidence exists for foddering until very late in European prehistory (*e.g.* Late Iron Age or later). Highland based pastoralists are therefore put at risk and would need to winter their stock in the lowlands.

Additionally, climatic shifts beginning at this time (*c.* 3300 BC) result in a decrease in the upper altitudinal limit for cultivation and the forest line (Bankoff and Greenfield 1984; Greenfield 1986). The result would be the opening up of highland pastures, and the opportunity for transhumant pastoralism. The lowland communities in the meantime are experiencing a combination of population dispersal throughout the lower altitudes and increased areas under cultivation in the low- and mid-altitudes would have meant that there would be less pasture available for domestic stock in the lowland. Herds would have to be moved farther away from settlements in order to find sufficient graze and forage. Transhumant pastoralism is an efficient response to the problem of less available and predictable pasture (Greenfield 1999; Sherratt 1980, 1982).

Sterud (1978, 383) notes that transhumance is '…a risk reducing economic strategy in an environment that is, in some sense, marginal or instable or where there is some threat to the livelihood of the human populations or their economic resources. Risks are reduced as the people transport the animals to the available foodstuffs, thus utilizing the landscape in an extensive manner'. In this manner, transhumance can be seen as a flexible response of the human populations to unfavorable conditions, increased marginality of environmental conditions for the domestic herds. Failure to respond would likely have resulted in increased marginality of economic and subsistence conditions for the human population.

This paper will investigate the hypothesis that transhumance initially occurs in the temperate zone of southeastern Europe at the advent of the Post Neolithic. Data collected for over an almost 20 year period by Haskel Greenfield will be used to test the hypothesis. Previous attempts by Greenfield to test this hypothesis utilized a mixture of cranial and post-cranial material from the central Balkans, but did not take into account issues of assemblage attrition (Greenfield 1986, 1988, 1999, 2001b).

This investigation will look specifically at the most attrition-resistant part of the assemblages – the mandibles and teeth data – in order to reconstruct the age and season of death information of domestic species. Harvest profiles will be presented from the analysis of the tooth wear and eruption data from the mandibles of domestic animals, specifically sheep, goat, cow and pig. This was supplemented by the secondary technique of cementum analysis in mandibular *Ovis/Capra* teeth. These data will be used to search for evidence of complementary movement of stock between highland and lowland areas.

Pastoralism and transhumant pastoralism defined

Since the focus of this investigation is the presence or absence of transhumant pastoralism in prehistoric periods in Europe, specifically within a temperate environment, it is first necessary to define both pastoralism generally and transhumant pastoralism specifically. Unfortunately, this is not an easy task, as there is currently no agreement in the definition of the various forms of pastoralism (Khazanov 1984; Maggi *et al.* 1990). The definition that will be utilized within the context of this investigation is as follows: pastoralism is a distinctive form of human subsistence economy in which domestic animals play a predominant, but not an exclusive role in the shaping of the economic and cultural lives of the people who depend on them (Galaty and Johnson 1990). Pastoralism is both a land use strategy and a system of animal production. Pastoralists are those who are largely dependent on their domestic stock for subsistence (Krader 1959).

There is a wide spectrum in the forms of pastoralism (Ehlers and Kreutzmann 2000). This is due to a range of factors and can include the quantitative and qualitative characteristics of the herds, the extent and range of mobility, degree of inclusion of agricultural products,

environment and ecological aspects of the region and the extent of ties with an external market (Logashova 1982). In general, pastoralism is grouped into two basic types, nomadic pastoralism and semi-nomadic pastoralism (or transhumance). On a very basic level, both types of pastoralism can be defined as the movement of domestic herds between altitudinally differentiated and/or seasonally complementary pastures. However, they can be further differentiated by a variety of means. For example, Chang (1993) differentiates nomadic pastoralism and semi-nomadic pastoralism (or transhumance) utilizing patterns of mobility. Transhumance occurs between fixed locations, summer and winter residences, whereas the nomadic pattern exhibits residential flexibility and a high degree of territorial mobility over space and through time (Chang 1993). In contrast, Khazanov (1984) places greater importance on the percentages of agriculture and pastoralism within the economic systems in his definition of the basic forms of pastoralism, rather than on degree of mobility.

Nomadic pastoralism (also known as pure pastoralism) has been characterized by the absence of agriculture, 'even in a supplementary capacity' (Khazanov 1984, 19). However, some researchers (*e.g.* Whittaker 1988) maintain that pastoralism has never existed in a pure form, with the total absence of agriculture. There is 'always a spectrum in the relative importance of one towards the other' (Whittaker 1988, 1). It seems that Khazanov (1984) simply takes a more extreme viewpoint.

Nomadic pastoralism involves the movement of people and animals within a large and defined geographic area according to a set schedule. This is an economic adaptation where the major economic orientation of the culture relies upon domestic stock (Barth 1961). In nomadic pastoralism, the majority of the human population migrates with their domestic herds year-round within a system of pastures. These pastoralists are highly mobile, move over vast areas, and are characterized by the absence of, or minimal investment in agriculture. This is the form of pastoralism practiced by the Basseri tribe of South Persia (Barth 1961). Their migratory pattern involves movement between arid steppes and mountainous environments in order to utilize extensive but localized pasturelands for their herds.

In contrast, semi-nomadic pastoralism or transhumance is characterized by an economy where pastoralism is the predominant activity but includes varying emphasis on agriculture as a supplementary activity. 'Even limited occupation with agriculture exercises a considerable influence on many aspects of the life of semi-nomads, in particular on the species-composition of herds, the routes and seasonal prevalence of pastoral migrations' (Khazanov 1984, 19). Within semi-nomadic cultural groups, two main alternatives are observed. It may be that the entire population in a given society is involved in both agriculture and pastoralism. Alternatively, there are specialized groups within the society that devote themselves primarily, or even exclusively, to pastoralism alongside groups that are principally occupied with agriculture (Khazanov 1984).

Transhumance is the seasonal migrations of domestic herds '(sheep and goats, cattle) between summer pastures in the mountains and winter pastures in the lowlands' (Ehlers and Kreutzmann 2000, 16). These periodical movements may involve journeys of several hundred kilometers or only a few kilometers (Walker 1983) and can be a vertical movement between altitudinally different areas or a lateral movement across the landscape. Transhumant pastoralism is part of a more broadly based economic system that incorporates crop cultivation and transhumance in a single economic scheme (Geddes 1983). The practitioners of this type of pastoralism, often-termed mixed or specialized pastoralism (Cherry 1988), are often semi sedentary (Geddes 1983).

Historically, transhumant pastoralism has been, and is, a significant part of the economy in the Mediterranean and the Balkans. 'The seasonal migration of herds and herdsmen take place even today on a fairly large scale in different parts of Greece, Albania, Yugoslavia and Bulgaria' (Rafiullah 1966, 28). Many researchers (Halstead 1981, 1996; Geddes 1983; Greenfield 1986, 1991, 1999, 2001a) agree that it was also an important element of the economy in prehistoric times (Harding 2000). As a result, this investigation will focus on a specific type of semi-nomadic pastoralism, transhumant pastoralism, rather than nomadic pastoralism.

Two basic types of transhumance have been defined for Mediterranean and temperate southern Europe – vertical and horizontal (lateral). In vertical transhumance, herds are moved up and down mountains in order to exploit seasonally available resources at different altitudes. In horizontal transhumance, herds are moved laterally within the same altitude zone in order to exploit seasonally available resources. The former is found under conditions of topographic variability (*e.g.* in the mountainous areas of the Alps and Dinarics). In the latter, there is usually very little topographic variability (*e.g.* on the steppes of eastern Europe and in the Hungarian/Pannonian Plain – Matley 1970; Szabadfalvi 1968; Vincze 1980).

Under conditions of vertical transhumance, two different strategies of settlement are found: normal and inverse. In normal transhumance, a permanent village base is maintained in the lowlands. In inverse transhumance, the permanent base is maintained in the mountains. The former is more common in the Mediterranean zone, while the latter is more common in the temperate zone (Alpine – Sterud 1978; Bartosiewicz and Greenfield 1999). In this way, herders are able to spend a substantial amount of time close to home.

Region under investigation

This investigation seeks to delimit the origins of vertical transhumant pastoralism within the temperate zone of

Fig. 1. Study area and site locations.

southeastern Europe. Specifically, one region within this large macro-region was chosen as the focus of the investigation – the central region of the Northern Balkans (Fig. 1). This area is actually an arbitrary division that has no defining topographic, geographic or political borders. It can be defined to include Serbia and the Vojvodina, northwestern Bulgaria and southwestern Romania (the Banat and Oltenia) (Greenfield 1986). Specifically, it lies within the Middle Danube Drainage and is the region encompassed within the arc of the Carpathian, Julian and Dinaric Alps and the mountain ranges of eastern and central Serbia. The boundary to the east is where the Danube passes through the Iron Gates (Ehrich 1965; Greenfield 1986). The Sava River forms the western boundary of the region while the Danube marks the northeast limit (Greenfield 1986). The topography of the region displays great variation within a small area.

This region was chosen because it is one of the few regions with sufficient zooarchaeological samples from highland and lowland areas that have been similarly analyzed. Also, Greenfield (1988, 1999) hypothesized that the Northern Balkans should be the first region in temperate Europe (north of the Mediterranean littoral) to experience the advent of transhumant pastoralism. The region is appropriate for this type of analysis because of the nature of its topography. Both highlands and lowlands exist, often juxtaposed in close proximity. This is the kind of environment in which one would expect transhumant pastoralism to exist. Historically, transhumant pastoralism is part of the regional subsistence system (*e.g.* Cviji 1918; Dedijer 1916). Hence, it is logical to expect that this practice extended back in time. Also, it is one of the few regions which have experienced vertical transhumant pastoralism in Europe that have easily available archived zooarchaeological data from a variety of environments (including highland and lowland).

Proposals for the temporal origins of transhumant pastoralism

Three major temporal 'moments' have been proposed as the points in time when transhumant pastoralism might have appeared. They are the following:

1. Early Neolithic – Transhumant pastoralism has long been proposed to have existed from the beginning of animal domestication in Europe. It is thought to be either a continuation of the migratory patterns of Mesolithic indigenous hunter-gatherers who adopted domestic animals into their repertoire (Geddes 1982; Sterud 1978) or appeared as a natural consequence of pastoralism during the Neolithic periods (Barker 1975; Chapman 1981, 1982; Hesse 1982; Hole 1978; Maggi *et al.* 1990; Wheeler Pires-Ferreira 1975).
2. Early Post Neolithic – *The Secondary Products Revolution* model posits that the diffusion of new production technologies and domestic breeds from the East at the onset of the Post Neolithic (Eneolithic or Early Bronze Age) enabled domestic animal exploitation patterns to shift from *primary* (meat, hide and bone) to *secondary* products (wool, milk and traction). Herds increased in size to more effectively produce secondary products. To avoid placing strains upon local economies (to produce and store winter fodder), herds were moved to unoccupied highland pastures for the summer and returned to the lowlands with the onset of inclement weather (Sherratt 1980, 1982).
3. Iron Age (or later) – Transhumant pastoralism is historically known from vast areas of the Mediterranean littoral by classical times (*e.g.* Dalmatia and Greece during the Roman era – Antonijevi 1982; Halstead 1987, 1990; Maggi *et al.* 1990; Sterud 1978). The large scale long distance specialized transhumant adaptations characteristic of the area (Antonijevi 1982; Sterud 1978) and elsewhere in southern Europe (Chang and Tourtelotte 1993; Halstead 1981, 1987; Lewthwaite 1981, 1984) appear to be very late (early historical periods) phenomena. Specialized transhumant pastoralism has been hypothesized to be a function of the appearance of large urban markets and productive specialization that appear in Classical or Medieval times (seen also in the Near East at an earlier time – Lees and Bates 1974; Cribb 1991). As a result, it can be hypothesized to be a result of the formation of early complex societies in the Iron Age or with the introduction of the Roman era.

Hypotheses

It is possible to create a series of testable hypotheses for each of these three theorems. Transhumant pastoralism should be evidenced by the appearance of a complementary culling pattern of domestic livestock between highland and lowland sites. This hypothesis is proposed based on the predictability of the transhumant movement of domestic stock. The herd will move into highland pastures in the early spring, soon after lambing/calving occurs, and will return to the lowlands during the autumn. In a subsistence economy, the age groups that are slaughtered in the highlands and the lowlands will be different. For example, Greenfield proposed (1999, 19) the following expectation under conditions of vertical transhumant pastoralism:

> Excess immature (infants and juveniles 0–8 months) individuals would be culled from the herds while they are in the highland pastures. In the lowlands, it would be the excess sub-adults and adults who would be selected for slaughter, since there are no juveniles or infants present. As a result, the age structure within the harvest profiles from highland and lowland settlements should be complementary.

Site	Superimposed strata	Weathering
Blagotin	Deep	Low weathering
Foeni-Salaş	Shallow	Medium weathering
Kadica Brdo	Deep	Low weathering
Livade	Shallow	Very high weathering, except in deep pits
Ljuljaci	Shallow	Medium weathering
Megalo Nisi Galanis	Deep	Low weathering
Novačka Ćuprija	Shallow	Medium weathering
Opovo	Deep	Low weathering
Petnica	Deep	Low weathering
Stragari	Deep	Low weathering
Vinča	Deep	Low weathering

Fig. 2. Summary of strata and weathering.

In other words, those youngest age cohorts slaughtered in highland sites are expected to be missing from lowland sites and vice versa. The season of death should also show complementary slaughter patterns between highland and lowland sites. The Null hypothesis obviously would be that the lack of evidence for regionally complementary domestic herd harvest profiles between highland and lowland sites would indicate the absence of transhumant pastoralism.

These hypotheses place significant emphasis on the presence or absence of the youngest age classes for all the domestic species. It is well recognized that the remains of the very young age classes are very fragile and that 'a very high proportion of those originally present in archaeological contexts would be lost through pre- and post depositional processes and excavation procedures' (Cribb 1984, 91; Munson 2000, 391). The depth of deposits, the degree of weathering of remains and the extent of sieving at sites were variable (Fig. 2 and 3). In order to control for differential attrition of age classes, Munson (2000) goes as far as to exclude the consideration of neonatals and notes only presence/absence. By focusing only on mandibular remains, this issue is somewhat controlled. In order to overcome these limitations in this investigation, the focus will be on the slightly older age groups in the herds: specifically the 2–6 month and 6–12 month groups in sheep/goat and the 1–8 month and 8–18 month groups in cattle. The expected patterns for the lowland, mid-altitude and highland sites for each species are summarized in Fig. 4.

It should not be mistaken that we are implying the appearance of specialized professional long distance transhumant pastoralism during prehistory of temperate southeast Europe. Instead, we envision that this economic adaptation probably arose as a result of short-term movement of animals between highland and lowland pastures by shepherds embedded within villages. It is with this shift, where the animals are away from the village for a lengthy period of the year, that transhumance may become archaeologically identifiable. Long versus short distance transhumant migrations would have different archaeological signatures because of the differences in the scale of movement. Long distance movements by specialists require the construction of pens and huts in both highland and lowland pastures. These result in archaeological site formation, with the consequent creation of data to test the above hypotheses. In contrast, short distance village based herders rarely require the construction of such temporary structures, except where they are very distant from their home bases (*e.g.* among lowland herders who have moved into summer highland pastures). These differences are borne out by a plethora of ethnoarchaeological studies (*e.g.* Barker 1990; Baker 1999; Chang and Koster 1986; Nandris 1985, 1990) and should be apparent in the zooarchaeological data, as well.

Methods and techniques

Two techniques within zooarchaeology will be utilized in this investigation – tooth wear and eruption and dental cementum analysis. These two sources of data are used here because they are appropriate for testing the above hypothesis concerning herd movements.

Harvest profiles were created from the analysis of the tooth wear and eruption data from the mandibles of domestic animals. This technique will provide information on both age and season of death for each species. Mandibles are staged according to the wear patterns suggested by Grant (1975, 1978) and Payne (1973). The two systems of recording wear are merged following the methodology suggested by Hambleton (1999). Specimens that overlap several wear stages are proportionally allocated to the age stages based on the raw count data as proposed by Payne (1973). For raw data allocations, see Greenfield and Arnold (n.d.).

The results of the tooth wear and eruption analysis were supplemented by cementum analysis of mandibular *Ovis/Capra* teeth to provide additional seasonality estimates. Incremental growth structures have been observed in a variety of organisms. These may be present in mineralized tissues, such as bone, molluscs, teeth, otoliths, fish spines and antler pedicles (Pike-Tay 1991). Correlations between growth lines in teeth have been recognized for more than 30 years as the most reliable means of establishing age and season of death of individual specimens (Lieberman 1993a, 1993b).

Tooth wear and eruption and cementum analyses, while not new techniques in zooarchaeology (Lyman 1994; Reitz and Wing 1999), have not been previously

Site	Percentage Sieved					
	0%	1–10%	11–25%	26–50%	51–75%	76–100%
Blagotin				50		
Foeni-Salaş						85
Kadica Brdo		10				
Livade	0					
Ljuljaci	0					
Megalo Nisi Galanis						100
Novačka Ćuprija						100
Opovo	0					
Petnica			20			
Stragari	0					
Vinča	0					

Fig. 3. Summary of sieving.

Ovis/Capra	**Age class**		
	0–2 months	**2–6 months**	**6–12 months**
Lowland	Present	Absent	Present
Mid-altitude	Absent	Present	Absent
Highland	Absent	Present	Absent
Bos taurus	**Age Class**		
	0–1 month	**1–8 months**	**8–18 months**
Lowland	Present	Absent	Present
Mid-altitude	Absent	Present	Absent
Highland	Absent	Present	Absent

Fig. 4. Expectations for movement in transhumant pattern.

applied to this problem at the same time. The mandibular remains of four species of domestic animals (*Ovis aries*, *Capra hircus*, *Bos taurus* and *Sus scrofa*) are examined for evidence of transhumant movement. The first three species are believed to have engaged in such movements, while the latter species is included as a control, as pigs are believed to not be commonly herded in a transhumant manner (Greenfield 1988, 1999). While pigs have been moved over long distances to markets (Halpern 1999), they tend to not be good stock for transhumant pastoralism since they easily lose weight during such migrations (Flannery 1965).

Data to be analyzed

There are two sources of data in this investigation – ancient and modern. The ancient data from the region are used to directly test the above hypotheses. The modern data were collected and used as a control for the application of both techniques used to test the hypotheses.

A. The ancient data can be divided into two types:

1. A very large computerized database on the zooarchaeology of the region that was compiled between 1977 and 1995 by one of the authors (HG) (Greenfield 1986 1994, 1996, n.d.a, n.d.b, n.d.c, n.d.d, n.d.e; Greenfield and Draşovean 1994; Greenfield and Fowler 2002). These data are archived at the University of Manitoba. Of these data, only the samples from ten archaeological sites in the central Balkans (and one from the Southern Balkans) were deemed to be of sufficient size for tooth eruption and wear analysis. Lowland sites include Foeni-Salaş, Livade, Novačka Ćuprija, Opovo, Stragari and Vinča. Mid-altitude sites, hypothesized to show harvest profiles most similar to the highland sites, include Blagotin, Ljuljaci and Petnica. The sample of highland sites is limited to Kadica Brdo. Data from the other sites were also examined, but were not useable in the final analysis due to problems of small sample size. Only the mandibular and loose tooth samples that included ten or more samples per species and per period were considered in the final analysis (Fig. 5–7). Sample sizes lower than ten were considered too small and excluded from the analysis.

Harvest profiles were constructed from the analysis of the tooth wear and eruption data from the mandibles of domestic animals. This technique will provide better control over both age and season of death information for each species.

Site	No. of mandibles	No. of teeth	Total sample size
Blagotin			
Early Neolithic	42	47	89
Foeni-Salaş			
Early Neolithic	36	14	50
Kadica Brdo			
Early Iron Age	97	111	208
Livade			
Late Bronze Age	11	0	11
Megalo Nisi Galanis			
Final Neolithic	12	32	44
Final Neolithic/ Early Bronze Age	4	9	13
Novačka Ćuprija			
Eneolithic	0	10	10
Early Bronze Age	8	24	32
Late Bronze Age	3	13	16
Petnica			
Late Neolithic	5	14	19
Eneolithic	9	4	13
Late Bronze Age	4	9	13
Stragari			
Middle Neolithic	7	15	22
Vinča			
Late Neolithic	32	0	32
Middle Bronze Age	13	10	23

Fig. 5. Sample size – Ovis/Capra.

Site	No. of mandibles	No. of teeth	Total sample size
Blagotin			
Early Neolithic	38	40	78
Eneolithic	3	9	12
Foeni-Salaş			
Early Neolithic	10	7	17
Kadica Brdo			
Early Iron Age	18	29	47
Livade			
Late Bronze Age	10	6	16
Ljuljaci			
Early/Middle Bronze Age	5	7	12
Opovo			
Late Neolithic	7	7	14
Petnica			
Middle Neolithic	15	7	22
Late Neolithic	4	15	19
Stragari			
Middle Neolithic	13	16	29
Vinča			
Late Neolithic	6	8	14
Middle Bronze Age	8	8	16

Fig. 6. Sample size – Bos taurus.

2. Selected samples of animal bone remains from many of the sites, including dental remains, were also available. Selected samples from two sites, Kadica Brdo (Knežina, Bosnia), a highland site that includes material from the Early Iron Age, and Vinča (Belo Brdo, Serbia), a lowland site that includes material from the Late Neolithic, Eneolithic and Middle Bronze Age were sectioned for cementum analysis. As cementum can easily be stripped from the tooth as the result of post-mortem damage (Lieberman and Meadow 1991), only Lower Molar 1's still encased in the mandible were selected for the archaeological sample.

The modern comparative data of *Ovis aries* and *Capra hircus* mandibles with teeth were collected from livestock breeders in Manitoba. Tooth wear and eruption data were recorded on all mandibles and a sample of teeth was selected for cementum analysis. The purpose of a modern control sample is to establish the time of formation of incremental growth structures in the cementum in order to apply this information to the study of archaeological samples (Burke and Castenet 1995).

A sample of sheep and goat skulls was collected from August 2000 to March 2001 from local Manitoba abattoirs or slaughterhouses. Approximately six sheep per month were collected from Carmen Meats in Carmen, MB. The goats were collected from the Prairie Abattoir in Portage la Prairie (Manitoba, Canada). The abattoir slaughtered two animals per week, which were collected each month. The utilization of these local animals is considered applicable to archaeological material in the Balkans because the animals are obtained from an environment with roughly similar patterns of seasonality. The animals of the comparative collection are raised on small-scale farms

Site	No. of mandibles	No. of teeth	Total sample size
Kadica Brdo			
Early Iron Age	42	7	49
Livade			
Late Bronze Age	26	1	27
Ljuljaci			
Early/Middle Bronze Age	18	2	20
Novačka Ćuprija			
Early Bronze Age	6	4	10
Opovo			
Late Neolithic	10	1	11
Petnica			
Middle Neolithic	12	1	13
Late Neolithic	11	2	13
Eneolithic	8	2	10
Vinča			
Late Neolithic	34	0	34
Middle Bronze Age	19	1	20

Fig. 7. Sample size – Sus scrofa.

in Manitoba. They are domestic farm animals raised with seasonal differences both in food availability and seasonal environment.

All the goats were born in the month of April, with a mean birth date estimated by the producer to be April 15th. The goats range in age from 6 months to a year and a half. As the pattern of slaughter was two animals per week and the specimens were collected at roughly the middle of each month throughout the collection period, date of death was estimated over a period of two months. This changed through the time of collection when collection was at the end of each month.

It was possible to obtain several older sheep from a private producer who raises sheep for wool. This small sample included one sheep specimen that was four and a half years old (54 months) and two animals that were a year and a half old at death. These were included in order to expand the age range covered by the sample. Additionally, two older sheep with no age information that were collected from the abattoir were included. As a result, the final modern comparative collection consists of both sheep and goat. There are forty-three animals, twenty-nine goats and fourteen sheep, in the sample that compares tooth eruption and wear. The thin sectioning sample consists of nineteen animals, fourteen goats and five sheep.

It was not detrimental to the analysis to include both sheep and goats in the sample. They are often lumped together in zooarchaeological investigations due to difficulties in reliably distinguishing the two species (Payne 1973). The teeth of sheep and goat are very similar in structure and size (Hillson 1986). Other researchers have utilized the application of goat thin sections to *Gazella gazella* (Lieberman 1993b) based on the close phylogenetic relationship (family Bovidae).

The sample utilized in this investigation was limited by the paucity of highland sites, of which there is only one (Kadica Brdo). However, the mid-altitude sites are hypothesized to be a relevant substitute in that they should show harvest profiles most similar to the highland sites in the transhumant movement of herds. This is because the over-wintering of herds in these mid-altitude regions would be difficult without sufficient shelter for the herds and collected fodder. As such, the marginal environment of the mid-altitude sites in the region, like the highland sites, would force the movement of domestic herds out of this area during the colder months of the year (*i.e.* transhumance). This is in contrast to the lowland sites where the variety of microenvironments in these areas can provide sufficient graze and water for herds year-round. As discussed earlier, there is no environmental factor that forces the transhumant movement of lowland herds.

Tooth wear and eruption results

In order to establish seasonality through the analysis of tooth wear and eruption, it is necessary to link the age of the animal established using the tooth wear with the date of birth. In the Northern Balkan area, the time of lambing/calving for all the major transhumant domestic species (cattle and sheep/goat) considered in this investigation is February. As the herds would not be moved immediately after lambing/calving, the herd would be found in the lowland areas from February to April. It is hypothesized that herds would then be moved into the highland areas from roughly May to September. The domestic herds return to the lowland areas in the autumn (roughly October) (Greenfield 1999).

In the transhumant movement of domestic ovicaprid herds, it is expected that the youngest age group (class A, 0–2 months) would be found only in the lowlands and would indicate a late winter/spring occupation. As the herds move into the highlands from roughly May to September, the presence of the next age stage (class B, 2–6 months) would be expected only in the highland areas and would indicate occupation from May to August, or a late spring/summer occupation.

Unfortunately, the age stages that are established for cattle (Higham 1967; Halstead 1985) and utilized here to establish absolute age are not fine enough to enable the identification of seasonal movement of herds. As with sheep/goat, calving occurs in the lowlands before the

movement into highland areas. Therefore, the youngest age class (0–1 month) is expected to be found only in the lowland sites if there is transhumant movement of herds. This would indicate a late winter/early spring presence. The paucity of this age group due to the taphonomic issues discussed above limits the seasonality information that can be obtained.

The second youngest age class for cattle is 1–8 months. The seasonality information that can be gained by the presence of this age group extends from the early spring through to the late autumn. The end of this period extends into the time when the herd is hypothesized to have moved back down to the lowland areas before the onset of winter. While it is expected that this age group (1–8 months) would dominate the mortality profiles of the highlands according to the hypotheses presented, the age classes utilized for cattle do not enable the same type of control that the sheep/goat age classes provide. They are not fine enough. It would be ideal to be able to split the 1–8 month age class into finer categories to enable more precise seasonal distinctions and age classes. However, there is as yet no valid analytical justification for this. As a result, the seasonality information that can be obtained from the 1–8 month age class extends from the spring into the late autumn (March-October). As a result, this age class for cattle is of little use to the questions of this investigation. As a result, the cattle data are of limited use.

Seasonal statements of pigs are based upon a single birthing period during the year. This is because pigs were not kept ethnographically in stalls or fed throughout the year in this region. Instead they were left to forage in the forests with a pig herder. Whenever pigs were needed for food the herder brought back one or more (Halpern 1999). As a result, it is unlikely that the modern conditions for multiple births throughout the year would have occurred in the past.

The birth month for pigs is hypothesized to be the same as for sheep/goat and cattle – February. As such, the occurrence of the 0–2 month age class indicates a late winter/early spring occupation of the site. The 2–7 month age group would indicate a summer/autumn occupation and the 7–14 month group would indicate an early winter occupation.

Sus scrofa dom

Domestic pig can be considered a control for the transhumant movement of herds. It would be expected that the exploitation patterns of pig should not change over time as these animals were not subjected to the transhumant movement of either cattle or sheep/goat that is hypothesized to occur at the Late Neolithic/Post Neolithic juncture. This is due to the fact that pigs are less suited to the types of movement that are required of transhumant herds. Although some researchers have noted that pigs are capable of the movement, such as the driving of herds long distances to market (Halpern 1999), this tends to be a one time movement that should not be equated to the regular movements expected in transhumance.

While the Early Neolithic sites of Foeni-Salaş and Blagotin did not have sufficient pig remains to contribute to the construction of harvest profiles all other major temporal periods are covered. The profiles indicate exploitation for meat and the presence of very young individuals. The presence of these earliest age groups (0–2 months through to 7–14 months) indicates that herds were present in some proximity to the site during all seasons, which confirms the hypothesis that no domestic animals are moving between highland and lowland sites. In some sites the youngest age group (0–2 months) is absent, likely the result of taphonomic issues, such as the differential destruction of younger age classes at the site (Cribb 1984, 1991; Greenfield 1986; Munson 2000). However, the presence of subsequent age groups (2–7 months through to 7–14 months) indicates that herds were present in some proximity to the site during all seasons. A summary of the major periods is presented in Fig. 8.

As predicted, the exploitation pattern of pigs does not change significantly over the entire time period considered in this investigation. Statistical analysis of sites of the major periods (Late Neolithic Petnica, Eneolithic Petnica, Early Bronze Age Novačka Ćuprija and Early Iron Age Kadica Brdo) indicate no statistically significant changes ($x^2 = 9.396$). The exploitation of pigs for their primary products continues to be the dominant feature of all of the pig harvest profiles likely due to the lack of secondary products available from pigs. Most importantly for the investigation into the origins of transhumant pastoralism, there is no difference in the exploitation patterns of domestic pig between highland and lowland sites either before and after the Late Neolithic/Post Neolithic juncture or at any other time.

Ovis/Capra

Separate harvest profiles for *Ovis aries* and *Capra hircus* were not possible to produce. Only three sites had sufficient samples of *Ovis aries* remains to produce harvest profiles and no sites had sufficient remains of *Capra hircus*. Therefore, the remains of both taxa were combined in order to achieve sufficient remains for analysis. The drawback of this approach is that it is difficult to separate out the pattern of sheep versus goat. This is somewhat negated by examining the frequency distribution of sheep and goat in each site. In every case, sheep remains far outnumber those of goats. Goats tend to be an insignificant part of total identified assemblages. In addition, most previously identified goat remains were from adult individuals (Greenfield 1984, 1986, 1988, 1991, 1994, 1996). Therefore it is proposed that the perceived pattern probably represents the remains of sheep with only a slight influence by goats on the older age classes.

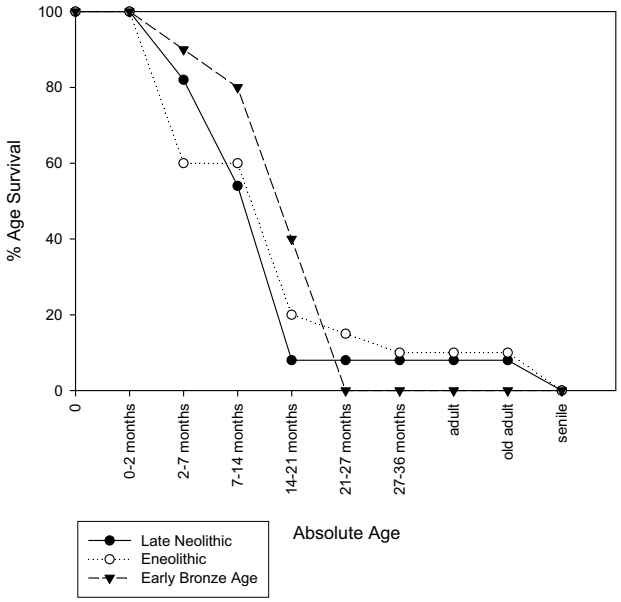

Fig. 8. Summary of inferred Sus scrofa *harvest profiles – Major periods.*

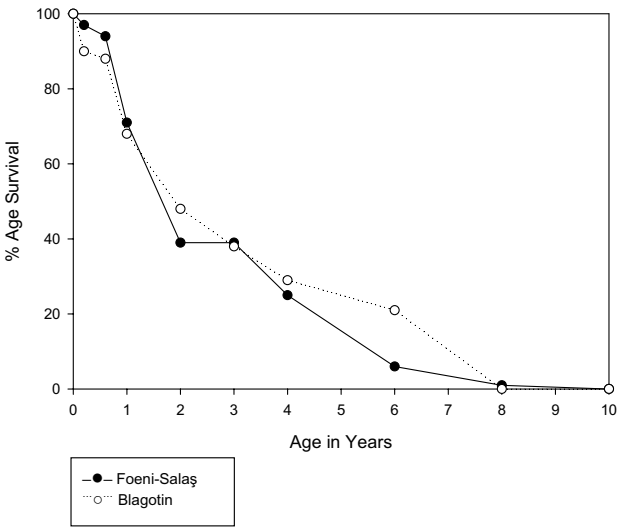

Fig. 9. Inferred Ovis/Capra *harvest profiles – Early Neolithic sites.*

In the Early Neolithic, both the lowland site of Foeni-Salaê and the mid-altitude site of Blagotin have sufficient sample sizes to produce harvest profiles for *Ovis/Capra* (Fig. 9). Statistical analysis indicates that there are no statistically significant differences between the profiles of Foeni-Salaş and Blagotin ($x^2 = 6.501$). The presence of the earliest age classes (0–12 months) in both Early Neolithic sites implies a year-round availability of the herds. This, in turn, suggests a non-transhumant movement and continuous culling of the animals, and residential stability throughout the year. There is no evidence for complementary harvest profiles between the sites and it can be concluded that transhumance is not occurring from Blagotin and Foeni-Salaş.

The harvest profile from the lowland Middle Neolithic site of Stragari shows the same pattern as those from Early Neolithic (Fig. 10). What is unusual about this profile in comparison to the Early Neolithic is the complete lack of the oldest age groups (3–4 years through to 8–10 years). However, these age stages are not sensitive to the hypotheses being tested. It is expected that the 0–2 month age class would be present at Stragari. The absence of the 0–2 month age class would normally imply that the animals are not being born in and around the site. The absence of this age class may be because this is an unsieved sample, but such remains are present in other unsieved or partially sieved samples. The presence of the 2–6 and 6–12 month age classes would indicate that the herds were around the site for the majority of the year. The continuity of occupation and exploitation of these age classes would imply that there is no evidence for transhumance during this period.

Mid-altitude Petnica and lowland Vinča represent Late Neolithic assemblages of *Ovis/Capra* (Fig. 11). There are no statistically significant differences between the profiles ($x^2 = 0.6755$). While the absence of the youngest age groups (especially at Vinča) may be seen as an indication of transhumant movement in the Late Neolithic, this is not believed to be the case here. If transhumance was present, the second youngest age group (2–6 months) would be expected to be present in mid-altitude sites. The absence of both the 0–2 and 2–6 month classes in the mid-altitude sites (*e.g.* Petnica) would argue that these age classes were not being exploited. The absence of the youngest age groups from Late Neolithic Petnica, a mid-altitude site, would argue against the appearance of transhumance during the Late Neolithic.

The lowland site of Novačka Ćuprija and mid-altitude site of Petnica provide *Ovis/Capra* harvest profiles for the Eneolithic (Fig. 12). Chi square analysis indicates that there is a marginally statistically significant difference between these two sites in this period. While the usual p value is given as 0.0110, the exact p value is 0.048. If one were to consider only the usual p value, one might assume that the result is extremely significant. However, as it is the exact p value that corrects for small sample sizes (as is the case here), this indicates that the difference is not as strong as it is implied by the usual p value. If transhumance was occurring, these differences would be expected between mid-altitude Petnica and lowland Novačka Ćuprija at this time. If transhumance was to appear during the Eneolithic, then the 0–2 month class should be present at lowland sites. Can its absence be the result of differential attrition? The presence or

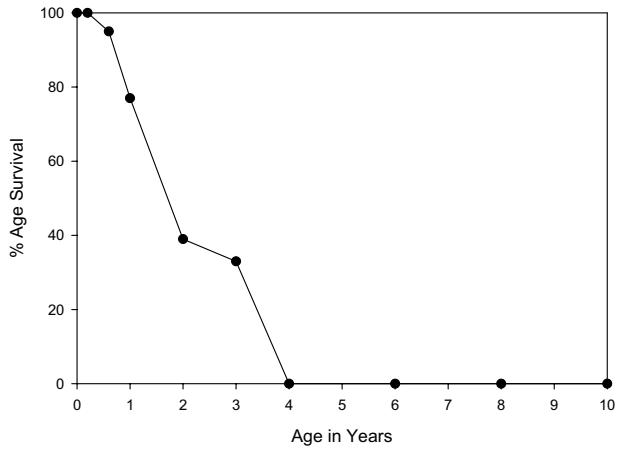

Fig. 10. Inferred Ovis/Capra *harvest profiles – Middle Neolithic Stragari.*

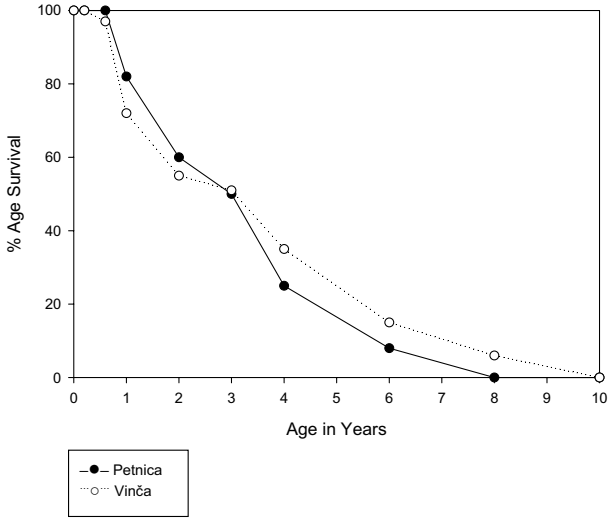

Fig. 11. Inferred Ovis/Capra *harvest profiles – Late Neolithic sites.*

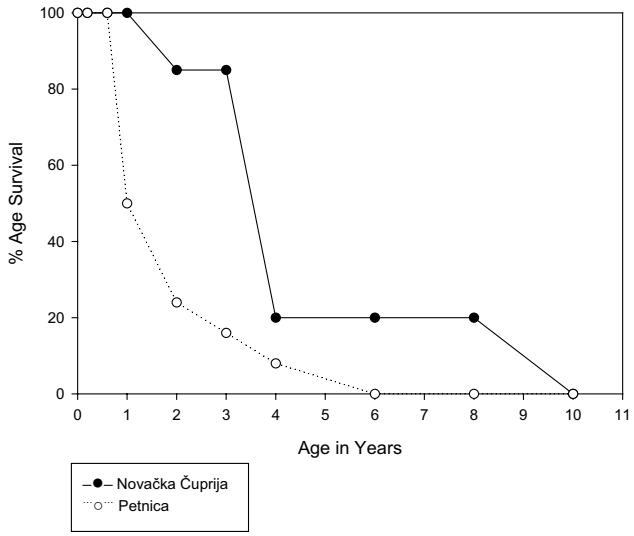

Fig. 12. Inferred Ovis/Capra *harvest profiles – Eneolithic sites.*

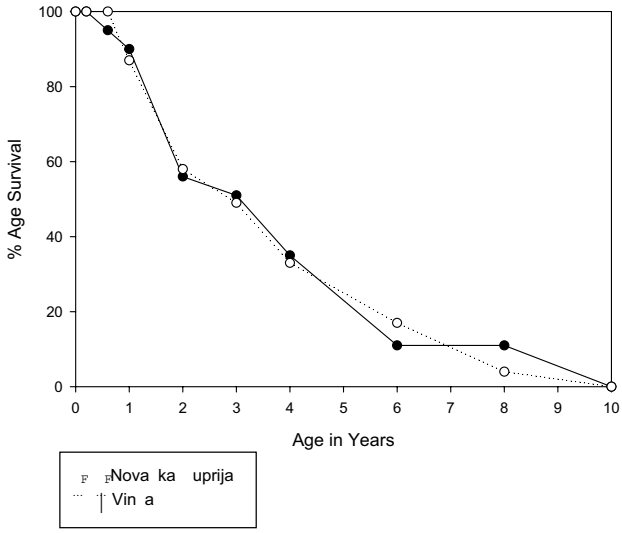

Fig. 13. Inferred Ovis/Capra *harvest profiles – Early/ Middle Bronze Age sites.*

absence of sieving is an unlikely force because Novačka Ćuprija was completely sieved. However, the assemblage was not deeply buried and it was subject to higher rates of weathering than many of the other contemporary assemblages (Fig. 2). The absence of the expected 0–2 month class at Novačka Ćuprija cannot be used to monitor the presence or absence of the transhumant movement of herds. As a mid-altitude site, Petnica is expected to show mortality profiles similar to those of a highland site. This would require the absence of the youngest age class (0–2 months) and the presence of the second youngest age class (2–6 months), which would indicate a seasonal presence in the highlands between May and August. However, both of these age classes are missing from the profile. As a result, it can be concluded that there is no evidence for transhumance since Petnica does not conform to the expectation of a highland site involved in the transhumant movement of herds. The mid-altitude site of Petnica is missing the expected 2–6 month class for a transhumant pattern and the lowland site of Novačka Ćuprija is missing its 6–12 month age group. In addition, the 6–12 month class is present in Petnica. The animals in this age class would be expected to have returned to their lowland pastures for the autumn and winter months. As a result, it is less likely that transhumant pastoralism is taking place at this time.

The lowland sites of Novačka Ćuprija and Vinča represent the Early/Middle Bronze Age (Fig. 13). The harvest profiles of Early Bronze Age Novačka Ćuprija and Middle Bronze Age Vinča are very similar. There are no statistically significant differences between the profiles of these sites ($x^2 = 2.566$). Since both Early/Middle Bronze Age samples come from lowland sites, they should have evidence of the 0–2 and 6–12 month age classes and absence of the 2–6 month class if transhumance is occurring. The 0–2 month age class is missing in both cases. The absence of the expected 0–2 month class is not surprising in these sites. It may be a function of assemblage attrition, given the lack of sieving at Vinča (Fig. 3). The slightly older age classes should be less affected (*cf.* Munson, 2000). The absence of the 2–6 month class and the presence of the 6–12 month class at Vinča are in accordance with the expectations for a lowland site involved in the transhumant movement of herds. The problem is that the presence of the 2–6 month class at Novačka Ćuprija is not in accordance with the expectations for a lowland site involved in the transhumant movement of herds. Therefore, the evidence for transhumance from this period is somewhat mixed. One site may be interpreted to be part of a transhumant system and the other may not. A major problem with this period is that there is the absence of mid-altitude and highland sites locations with sufficient data with which to compare them.

For the Late Bronze Age, three sites yield sufficient data: mid-altitude Petnica and lowland Novačka Ćuprija and Livade (Fig. 14). It would be expected that the lowland sites of Novačka Ćuprija and Livade would be similar to each other and significantly different from the mid-altitude site of Petnica. However, chi square analysis of the profiles from all three sites from this period indicates that there is no statistically significant difference between them ($x^2 = 6.007$). It is probable that the sample sizes are not sufficiently large to reflect the expected differences using statistics. In the Late Bronze Age, the presence of the 2–6 month class and the absence of the younger class would indicate the presence of herds around Petnica during this crucial period of the year. It is in accordance with expectations that highland herds, and not necessarily lowland herds, must be moved in a transhumant fashion. The presence of the 6–12 age class at Petnica, however, would not be in accordance with expectations that transhumance has appeared. The absence of the 2–6 month age class at both lowland sites (Livade and Novačka Ćuprija) is expected if they are participants in a transhumant economy. The lack of the 0–2 month class from both the mid-altitude and lowland sites is not surprising. It may be a function of assemblage attrition due to low or lack of sieving at Petnica and Livade, respectively (Fig. 3). The absence of this age class at Novačka Ćuprija is surprising since this is where it would be expected. This is a sieved site. Its absence may be a reflection of the lower rate of preservation at Novačka Ćuprija than many of the other sites (Greenfield 1986). The presence of the 6–12 month class at Novačka Ćuprija would be in accordance with expectations for a transhumant economy. But the absence of this class at Livade is contrary to expectations. The complete absence of all individuals at Livade, with its high rate of weathering, is not unexpected (Fig. 2). The result, however, is that no conclusion concerning the presence or absence of transhumance at Livade is possible. This may imply that animals are not being moved in a transhumant fashion from lowland sites. However, as discussed in an earlier section, it is not hot and dry enough in the central Balkans (contrary to the Mediterranean) to force this pattern for lowland sites.

The harvest profile of the Early Iron Age highland site of Kadica Brdo (Fig. 15) shows a very low mortality in the youngest age groups (0–6 months), followed by rapid mortality of the 6–12 month and 1–2 year age groups, followed by a slowing in the 2–3 year group, and a final very rapid mortality rate between 3–4 years and 4–6 years. There is a very low rate of the older age groups (6–8 and 8–10 years) in comparison to the earlier groups. There are no gaps in the youngest age groups (0 to 1–2 years). The remains from Kadica Brdo are not indicative of the presence of transhumance. The harvest profile shows the presence of the youngest age classes that implies a year-round availability of the herds. This, in turn, suggests a non-transhumant movement and continuous culling of the animals, and residential stability throughout the year. It may be that at this later period, highland areas have developed enough to support year-round residence of domestic herds through the production and storage of winter fodder and appropriate shelter available for the animals.

The site of Megalo Nisi Galanis was included in the analysis in an effort to make a comparison with the Southern Balkans. Of all the taxa, only the *Ovis/Capra* sample sizes were large enough to produce harvest profiles (Fig. 16). The Final Neolithic period of the Southern Balkans is temporally contemporaneous with the Eneolithic period of the Northern Balkans. Therefore, one would expect to see a profile similar to those seen in the Post Neolithic phases of the Northern Balkans. The harvest profile shows the presence of the youngest age group (0–2 months), the absence of the next age group (2–6 months), and a high mortality rate of the subsequent age groups. This appears to fit the expectations of a lowland site involved in a transhumant movement of herds. However, Megalo Nisi Galanis is a site located on a plateau, which makes it more of a mid-altitude site. As a result, one would have expected the opposite pattern. The harvest profile of the Final Neolithic/Early Bronze Age from Megalo Nisi Galanis also does not fit the pattern hypothesized for a mid-altitude site involved in transhumance. This would imply that a different pattern existed between the Northern and the Southern Balkans. In order to have an effective comparison between the

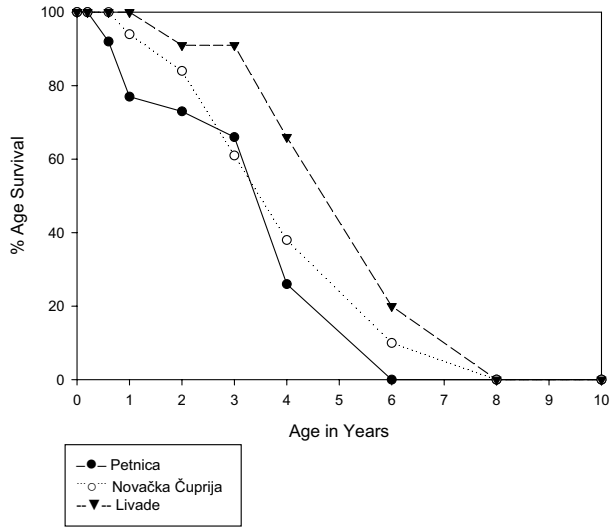

Fig. 14. Inferred Ovis/Capra *harvest profiles – Late Bronze Age sites.*

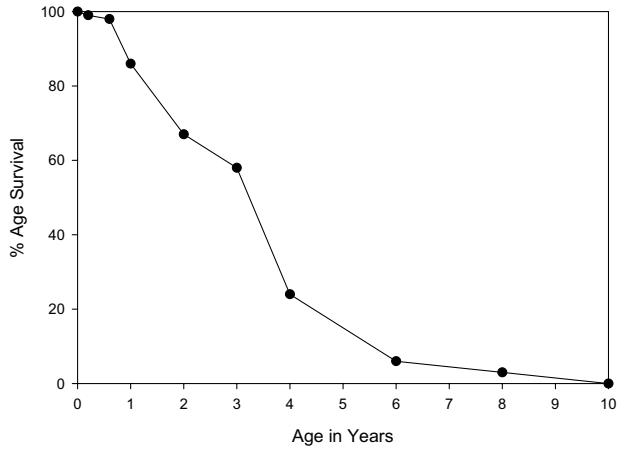

Fig. 15. Inferred Ovis/Capra *harvest profiles – Early Iron Age Kadica Brdo.*

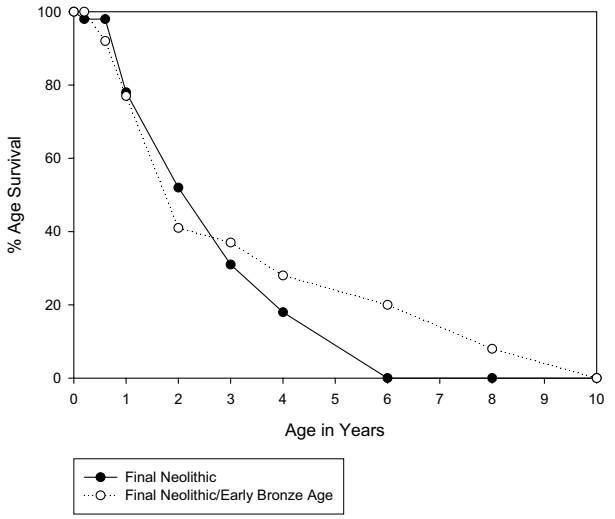

Fig. 16. Inferred Ovis/Capra *harvest profiles – Megalo Nisi Galanis.*

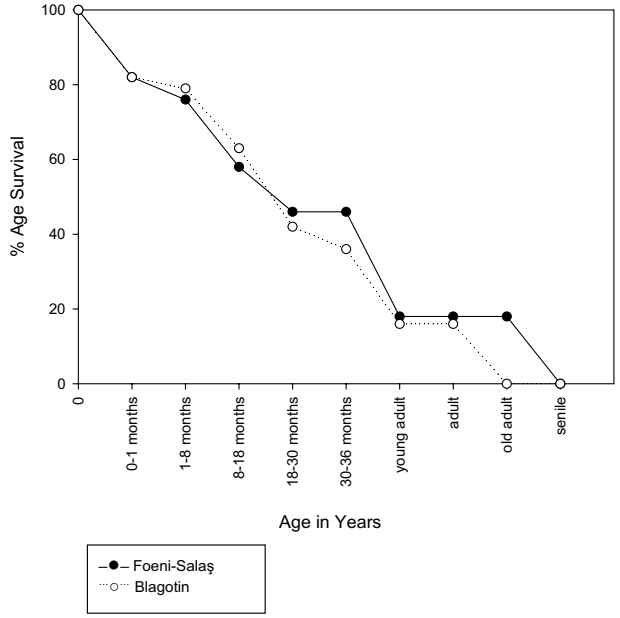

Fig. 17. Inferred Bos taurus *harvest profiles – Early Neolithic sites.*

transhumant patterns of these regions, a larger sample of sites from the Southern Balkans is required including both highland and lowland areas.

Bos taurus

In the Early Neolithic, both the lowland site of Foeni-Salaş and the mid-altitude site of Blagotin have sufficient sample sizes to produce harvest profiles for *Bos taurus* (Fig. 17). The harvest profiles from the two sites do not have statistically significant differences ($x^2 = 2.147$). Additionally, there are no statistically significant differences between an average *Bos taurus* pattern and an average *Ovis/Capra* pattern ($x^2 = 1.536$) for the same period (Fig. 18). The profiles from Early Neolithic Foeni-Salaş and Blagotin show the presence of the youngest age classes (0–18 months). This implies a year-round availability of the herds which suggests non-transhumant movement and continuous culling of the animals, and residential stability throughout the year. The similarity between both profiles is remarkable, given that one is lowland and the other is mid-altitude. It would be correct to state that there is no evidence for complementary harvest profiles between them and that transhumance is notoccurring between highland and lowland areas.

The lowland site of Stragari and the mid-altitude site

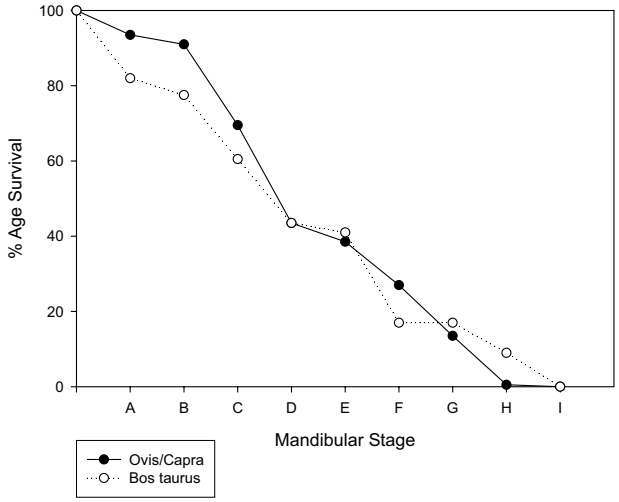

Fig. 18. Inferred harvest profiles Early Neolithic Bos taurus *vs.* Ovis/Capra.

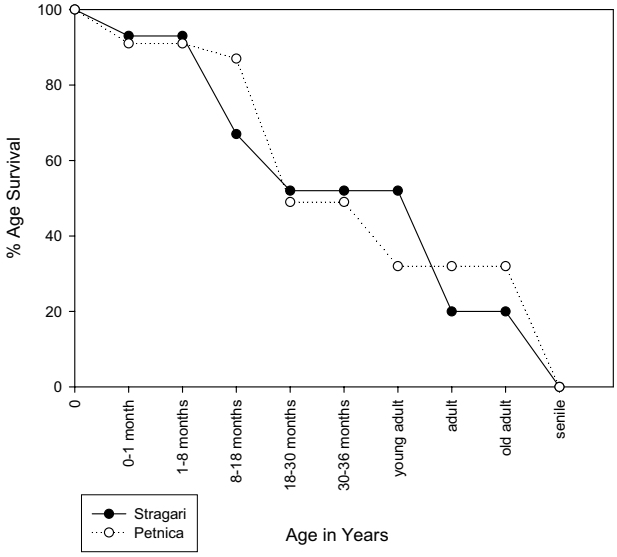

Fig. 19. Inferred Bos taurus *harvest profiles – Middle Neolithic sites.*

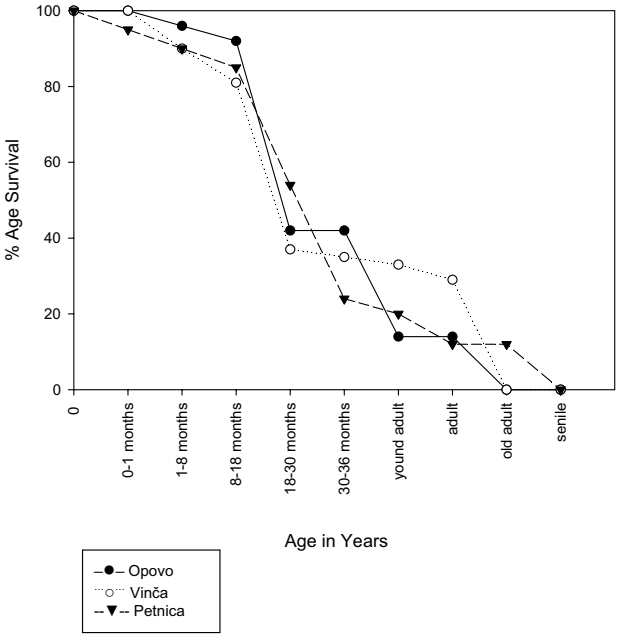

Fig. 20. Inferred Bos taurus *harvest profiles – Late Neolithic sites.*

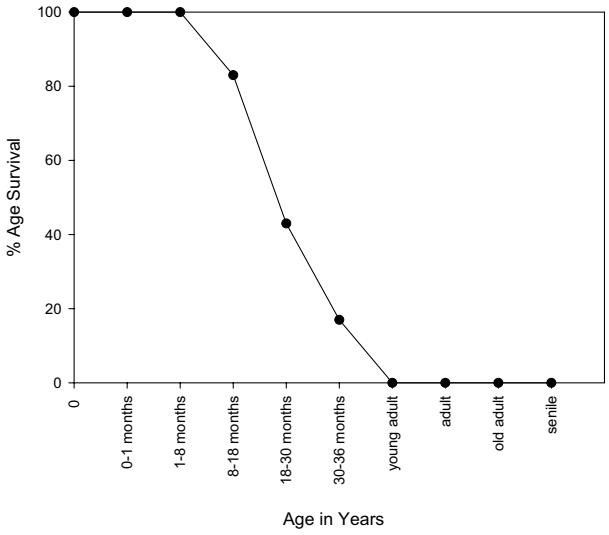

Fig. 21. Inferred Bos taurus *harvest profiles – Eneolithic Blagotin.*

of Petnica provide the Middle Neolithic *Bos taurus* harvest profile patterns (Fig. 19). These profiles show the same general pattern as those from Early Neolithic. While both sites have adequate sample sizes, Stragari (n=29) and Petnica (n=22), both are missing important age classes for this investigation. Significantly, while both sites include the remains of the 0–1 month age class, both are missing the 1–8 month age class. The statistical analysis indicates that there are some statistically significant differences between the profiles for this period (x^2 = 5.764). However, as the usual p value is greater than 0.05 and the exact p value is only slightly less than 0.05, this difference should only be considered to be a moderate effect. The harvest profiles from Stragari and Petnica would seem to imply the pattern expected for a lowland site where the herd is being moved in a transhumant fashion. However, this is unlikely since one is lowland and the other is mid-altitude. The absence of the same age class is therefore a function of some other variable, such as equivalent season of culling, than transhumance.

The Late Neolithic samples come from the lowland

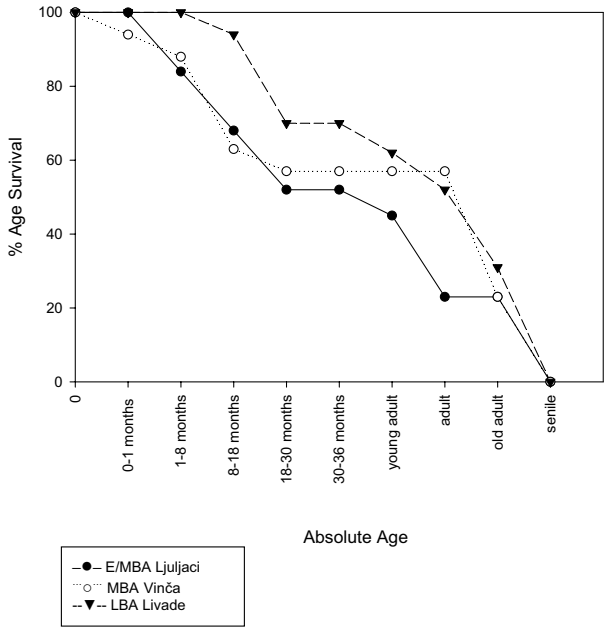

Fig. 22. Inferred Bos taurus *harvest profiles – Bronze Age sites.*

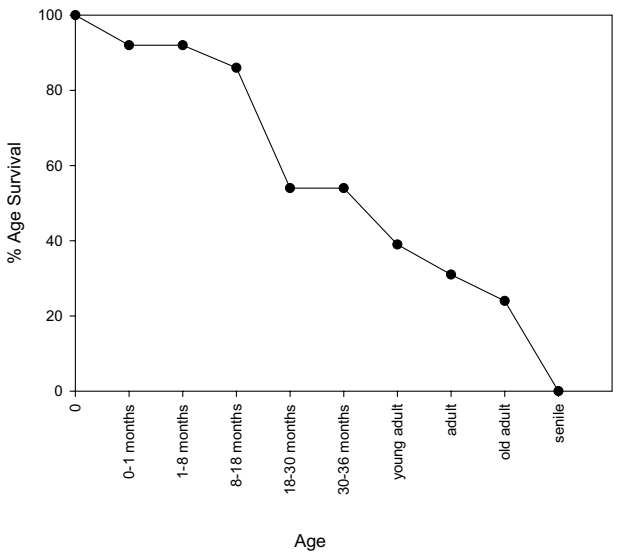

Fig. 23. Inferred Bos taurus *harvest profiles – Early Iron Age Kadica Brdo.*

sites of Opovo and Vinča, and the mid-altitude site of Petnica (Fig. 20). There are no statistically significant differences between the harvest profiles of the three Late Neolithic sites ($x^2 = 3.074$). The profiles from each of the sites indicate the presence of individuals in each of the young age classes (0–1, 1–8 and 8–18 months). This implies a year-round availability of the herds. In turn, this suggests a non-transhumant movement and continuous culling of the animals, and residential stability throughout the year. It would be correct to state that there is no complementarity between them and that transhumance is not occurring between highland and lowland areas. This pattern conforms to the pattern established in the Early Neolithic.

In the Eneolithic periods, only one site, mid-altitude Blagotin had a sufficient *Bos taurus* sample size (Fig. 21). The harvest profile shows a complete absence of the youngest age groups (0–8 months) followed by a steep mortality rate for the 8–18 month group through to the young adult group. There is the complete absence of the oldest age groups (adult, old adult and senile). Blagotin is a mid-altitude site, and would be expected to conform to the highland pattern within a transhumant strategy. There would be an expected absence of the youngest age classes (0–1 month). This is the pattern that is seen. However, as discussed above, this age class is unreliable as an indicator of transhumance because of taphonomic issues. One should then look at the expected presence of the next age group (1–8 months) that would be expected to dominate the harvest profile. The complete absence of this age class would indicate that the harvest profile of Blagotin does not conform to the expectations of a highland site involved in the transhumant movement of herds. A problem with this period is that there is an absence of comparable lowland site locations with sufficient data.

Three sites have sufficiently large samples for the Early/Middle Bronze Age. Early/Middle Bronze Age Ljuljaci represents a mid-altitude site, while the lowlands are represented by Middle Bronze Age Vinča and the Late Bronze Age Livade (Fig. 22). As Ljuljaci is a mid-altitude site the harvest profile is expected to show a highland pattern. Here, it seems that Ljuljaci shows the expected pattern of a highland site with the absence of the 0–1 month group and the occurrence of rapid mortality of the 1–8 month age group. One would also expect the absence of the next age class as the herd moves back into lowland areas for the winter. However, the harvest profile shows a continuation of the rapid mortality of the earlier age class. As a result, Ljuljaci appears not to conform to the expectations of a transhumant movement of domestic herds. The lowland site of Vinča shows both the presence of the youngest age class (0–1 month), which is expected, and the presence of the next age class (1–8 months) which is unexpected if there was transhumant movement of the herd. It appears that Vinča does not fit the transhumant pattern for lowland sites. The absence of the 1–8 month group is expected in the lowland site of Late Bronze Age Livade assuming a transhumant movement of the domestic herds. The presence of the next age group (8–18 months) also fits with the expectations of a transhumant movement. As such, it seems that Livade data imply that animals are being moved in a transhumant fashion.

The highland site of Kadica Brdo (Fig. 23) provides the only harvest profile for the Early Iron Age. There is

a very low mortality of the youngest age group (0–1 month) and a complete absence of the 1–8 month age group. A low mortality rate of the 8–18 month group and rapid mortality of the 18–30 month group follow this. The 30–36 month group is missing from the profile. There is a rapid mortality rate of the young adult group through to the senile one, although at a reduced rate from the previous age groups. Once again, the remains from Kadica Brdo are not indicative of the presence of transhumance. The harvest profile shows the presence of the youngest age classes, which implies that this site was occupied at least during the early spring, which is not expected for a highland site involved in transhumant pastoralism. The absence of the 1–8 month age group is quite surprising and may be an indication of the absence of the herds or the result of assemblage attrition given the fact that a single individual represents the 0–1 month class. This merely highlights the difficulty of identifying transhumance with such data. The data most likely can be used to interpret the presence of herds in the area at least during the early spring months, which suggests a non-transhumant movement and continuous culling of the animals and residential stability of the herd around the site throughout the year. It may be that at this later period, highland areas have developed enough to support year-round residence of domestic herds through the production and storage of winter fodder and appropriate shelter available for the animals.

Cementum analysis results

Data from two sites were used in this part of the analysis since few of the sites had sufficient samples of intact teeth useful for cementum analysis. In the Early Iron Age highland site of Kadica Brdo, the archaeological thin sectioning sample consisted of ten teeth. Of these, the slides of four teeth were unreadable, leaving six readable slides. From the lowland site of Vinča, the nine teeth were sectioned, but five were unreadable, leaving four readable slides. In both samples, the number of increments present agrees with the age estimates obtained from tooth wear and eruption.

For seasonality determination in the Kadica Brdo sample, the nature of the final increment was determinable on only four of the readable slides (Sample numbers KB2, KB4, KB6 and KB10). These were all determined to be a growth zone. However, the determination of seasonality estimates was more problematic for the site of Vinča. The final increment was determinable for only three of the readable slides (V1, V6 and V10) and there was disagreement on its nature. Based on the observations established with the modern comparative sample, the final increments were interpreted by E. Arnold as the forming of an annulus with a bright outer increment. However, determinations made by Dr. A. Burke indicated a final zone. nfortunately, this disagreement could not be resolved. It must be realized that the conclusions based on the modern comparative are limited by the extremely small sample size. While the modern comparative includes nineteen animals, which is extremely small already, the observations regarding increment formation are based on a single animal.

Additional problems exist with regards to the application of the modern comparative to the archaeological sample. As the birth month in the Northern Balkan region is known to be February, and the birth of the modern comparative is known to be April/May, this implies a certain amount of incompatibility between the comparative and the archaeological sample. While the modern comparative can be used to establish that the increments formed by sheep and goat correspond well with absolute age, this is not the main focus of the archaeological sample. It was hoped that the thin sectioning of the archaeological teeth would provide seasonality information, as the primary technique of tooth wear and eruption is limited in its ability to establish this information. As the timing of the birth of these animals is significantly different, it can reasonably be assumed that the timing of the formation of the increments will also differ. The ideal would be the collection of a modern sample from the Northern Balkan region.

One may be tempted to maintain that the final increments in the archaeological samples from the highland and lowland areas are complementary. The slides from the lowland site of Vinča show an annulus as the final increment (cold season), while the slides from the highland site of Kadica Brdo show a growth zone as the final increment (warm season). As such, while the timing of the formation of these increments may only be tentatively established based on the comparative collection, there is a complementary pattern of seasonality between the highland and lowland sites. However, as the observations of the two investigators do not agree, one cannot use this result with confidence.

A final problem to consider, when attempting to draw any conclusions from this limited archaeological thin sectioning sample, is the period of the sites. The sample from the lowland site of Vinča is from the Late Neolithic. As transhumance is not hypothesized to be occurring at this time, the herd should be resident in this lowland site for the entire year. One would expect to find seasonality evidence for year-round occupation. Therefore, if one accepts either researcher's readings, the sample follows the expectation for the year-round presence of herds around the site. The highland site of Kadica Brdo, if involved in the transhumant movement of herds would be expected to show only a summer occupation, which it does. As such, while the sample from Kadica Brdo appears to conform to the hypotheses put forth in this investigation, it is severely limited by sample size as well as the lack of lowland sites of the same period.

Discussion

The evidence for the transhumant movement of domestic herds at the Post Neolithic juncture is mixed. The majority of the data provides insufficient evidence for the evaluation of the original hypotheses. It was expected that the exploitation patterns of pig would not change over time as these animals were not subjected to transhumant movement. The pig data conforms exceedingly well to these expectations. Statistical analysis does not indicate statistically significant changes between periods. There is no difference in the harvest profiles of domestic pig between highland and lowland sites either before or after the Late Neolithic/Post Neolithic juncture or at any other time.

The results from the Neolithic *Ovis/Capra* harvest profiles imply a year-round availability of the herds. This, in turn, suggests a non-transhumant movement and continuous culling of the animals, and residential stability throughout the year. It would be correct to state that there is no evidence for complementary harvest profiles between highland and lowland areas. Therefore, transhumance is not occurring during the Neolithic. This observation conforms to the expectations of the hypotheses of this research. Changes in harvest profiles of *Ovis/Capra* are seen in the Post Neolithic periods. However, only the Middle Bronze Age site of Vinča conforms to the expectations of the hypotheses and provides some suggestion of the presence of transhumant pastoralism. The harvest profile from Vinča shows an absence of the youngest age groups (0–2 and 2–6 months). As a lowland site, it would be expected to have evidence of the 0–2 and 6–12 month age classes, with an absence of 2–6 month age classes if transhumance is occurring. While the 0–2 month age class is missing, this group is most susceptible to taphonomic issues and differential recovery. The absence of the 2–6 month class and the presence of the 6–12 month class at Vinča are in accordance with the expectations for a lowland site involved in the transhumant movement of herds. In contrast, at Early Bronze Age Novačka Ćuprija, also a lowland site, there is the presence of the 2–6 month class. Therefore, the evidence for transhumance from the Early/Middle Bronze Age is somewhat mixed. One site may be interpreted to be part of a transhumant system and the other may not.

For *Bos taurus*, the profiles from the Neolithic periods imply a year-round availability of herds. This, in turn, suggests a non-transhumant movement and continuous culling of the animals, and residential stability throughout the year. It would be correct to state that the harvest profiles are not complementary between highland and lowland areas and that transhumance is not occurring. This observation conforms to the expectations of the hypotheses of this research. Again, changes in the harvest profiles are seen in the Eneolithic. In the Post Neolithic periods, the only site that provides the suggestion of the transhumant movement of herds for *Bos taurus* is the Late Bronze Age site of Livade. The absence of the 1–8 month group from this site is expected in a lowland site assuming a transhumant movement of the domestic herds. The presence of the next age group (8–18 months) also fits with the expectations of a transhumant movement. As such, it seems that the data implies that animals are being moved in a transhumant fashion.

For *Ovis/Capra* and *Bos taurus*, the Neolithic periods show that herds are resident year-round in the region. This was the expected pattern, indicating the non-transhumant movement of the herds. As the hypotheses are stated in this investigation, one would expect to begin to find evidence of the transhumant movement of herds in the Post Neolithic. However, the data were unable to adequately answer any questions about the transhumance.

As a result, the evidence for the transhumant movement of domestic herds is far from concrete. However, while the hypotheses cannot be fully tested with this material, the lack of evidence should not be considered to be proof of a lack of transhumant pastoralism in the region at this time. It may be the result of a lack of an appropriate sample, the lack of fitting hypotheses or the lack of better analytical techniques.

Several overriding methodological issues hampered this research. Sample size was the major limitation of the investigation (Fig. 5–7). Small sample size did not allow for the examination of every domestic species of interest, in each period, and at each site. Taphonomic issues, notably the extent of sieving and differential preservation of the age classes, were a major contributing factor to the small sample size. Finally, the sample was also limited by a lack of highland sites from the earliest periods of the Post Neolithic, specifically the Eneolithic and the Early Bronze Age. Only one site was considered to be a true highland site (Kadica Brdo).

Shennan (1988) maintains that samples of mandibles less than 15–20 should be considered too small to provide accurate harvest profiles. The minimum sample size should be 40 mandibles. As a result, less than 20% of the harvest profiles produced in this investigation can be considered reliable. This is an inadequate representation to make any conclusions about the origins of transhumant pastoralism. Therefore, even in profiles that show the expectations put forth by the major hypothesis of this investigation (Middle Bronze Age Vinča for *Ovis/Capra* and Late Bronze Age Livade for *Bos taurus*), these cannot be considered to be evidence of a transhumant movement of domestic herds. As a result, the major hypothesis cannot yet be adequately evaluated due to the lack of an appropriate sample.

The evidence for seasonality from the cementum analysis of the domestic *Ovis/Capra* teeth was limited and problematic. The thin sectioning results cannot provide any support for the hypotheses of this investigation. There was no evidence for a complementary seasonality of culling between highland and lowland sites. The same issues discussed above in regards to the tooth wear and

eruption data is a factor for the cementum analysis. The modern comparative collections are unfortunately small, as it was difficult to obtain animals that were older than a year and a half. This is due to the fact that *Capra hircus* is primarily raised for meat in Manitoba, and so is slaughtered before this age. A good sample of *Ovis aries* was equally difficult to establish, for even though these animals are raised primarily for wool in Manitoba, the majority of producers are small scale and slaughter a minimum number of animals within the year. Due to the fact that the modern comparative collection was limited by the absence of older individuals, this made the establishment of timing of increments difficult. This in turn, affects the conclusions presented for the archaeological sample. However, it can be stated with confidence that both sheep and goat develop increments in their dental cementum which correspond well with their absolute age. Again, the stated hypotheses were unable to be fully tested due to the lack of an appropriate sample.

While the presence of transhumance cannot be adequately evaluated due to the issues of sample size, what is evident is a significant shift in the organization of harvest profiles in the Post Neolithic. While this investigation cannot fully link these changes with transhumant pastoralism, the suggestion of an economic shift or reorganization of domestic animal exploitation practices is present in the data. As discussed above, an increasingly untenable situation for both animal and human populations was created by environmental changes and population dispersals and economic and political reorganizations at the advent of the Post Neolithic in the Northern Balkans. One of the responses to this situation was hypothesized to be the transhumant movement of domestic herds between highland and lowland regions. However, an equally valid response was also a diversification of economic strategies such as the use of the secondary products of animals. The advent of transhumance in southeastern Europe is hypothesised to occur at roughly the same time as the inclusion of secondary products in domestic animal exploitation strategies, *c.* 3300 BC (Greenfield 1986, 1988, 1989, 1999, 2001b).

Conclusions

At the advent of the Post Neolithic in the central Balkans there are substantial shifts in both the climate (and consequently the environment) and the organization and distribution of human populations across the landscape. Climatic data indicate the opening up of pastures at lower altitudes in the mountain zones. Demographically, the highlands are colonized for the first time, while the lowlands become filled with a plethora of small villages. The implication is that transhumant pastoralism becomes an important form of land use during this period.

While the data from this investigation has failed to concretely define the moment for the origins of transhumant pastoralism in temperate southeastern Europe we remain unconvinced that this movement across space is completely undetectable. The failure of this model to show transhumant movement of herds is due to the lack of a sufficient sample, both in terms of sample size and suitability of the sample to the chosen techniques (notably thin sectioning analysis). As the sample utilized for this investigation was collected over an extensive period of time (nearly 20 years), during which the technique of thin sectioning was only just developing, the sample was not fully appropriate for use. Using cruder techniques, Greenfield (1988, 1989, 1999) was able to demonstrate a shift in seasonality of culling between highland and lowland sites with the advent of the Post Neolithic. As a result, the techniques may be too sensitive and therefore inappropriate for the data.

The ecological incentives for the adoption of transhumance that occurred in the Post Neolithic and the proposed model for its detection based on complementary harvest profiles between lowland and highland areas are still considered. These hypotheses require a more complete zooarchaeological sample for testing. Furthermore, the model for defining transhumance with zooarchaeological data that is proposed here can also be extended for testing with other data sets from other regions and temporal periods.

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Colonisation, Migration, and Marginal Areas, (ed. M. Mondini, S. Muñoz & S. Wickler) pp. 118–120

13. A Review of the Session: Margins and Marginality

Anthony J. Legge

'Marginality' – as the contributors to this section variously note – is a term with many layers of meaning. Among those given in the Oxford Dictionary are those of the 'edge, border or boundary' and, perhaps closest to the sense in which the term is most often used in archaeology, 'close to the limit.' For most of us the concept of 'marginality' may be conditioned by a sense of alarm – frightening places where we would not know how to live and where we would be unlikely to survive. My own introduction to 'marginal' societies came during a childhood in Cambridge, a city with two institutions with extensive ethnographic collections, which left me with vivid impressions of the Inuit cultures. Both the Scott Polar Institute and the University Museum of Archaeology and Ethnography had remarkable displays. Those in the University Museum were an old-fashioned assemblage of spears, harpoons, kayaks and anoraks, stuffed with hand-written labels into an impressively large showcase of glass and mahogany. Old fashioned, yes – but riveting to the attention and amazing in the diversity of skills that were shown, the display now sadly dismantled. These exhibits, and an exposure to Robert Flaherty's documentary film *Nanook of the North* (1922), left me with a sense of awe for the inventiveness and adaptability of our species that remains to this day. My own notion of 'marginality' was thus formed by an understanding not only of the geographical remoteness of such peoples from my own existence, but also of the complexity of their adaptation, and with a profound respect for the manner in which they invented and survived. Appropriately, three of the contributions given here are from the polar extremes of the Americas – two from the northern margins and one from the southern end.

Alan Outram's paper powerfully highlights the importance of fat in the diet at these climatic extremes, building on the important work of J. D. Speth and others. In this sense, the Inuit diet is indeed at the margins of modern human experience. A diet high in protein, and low in vegetables and carbohydrate has its particular hazards if taken to extremes and if not balanced by a sufficient fat consumption. As Outram says in his introduction 'The more marginal the economy, in terms of meeting calorific needs, the more essential fat becomes.' Humans respond to this need by extreme bone processing, extracting the fat by roasting and boiling, the results closely related, as with most food processing activities, to the return rate in calories per hour so that the less valued bones are the least often processed. Outram has no problem with the idea that environmental stress determined human response, and that the state of the bone collections he describes can be an important means to measure the level of dietary stress within a community. This paper should serve as a reminder to the followers of the popular 'Atkins' diet and similar schemes for weight loss, in which the food intake is restricted in carbohydrate, but not in fats and proteins – they are reinventing the wheel, but not necessarily to their own best advantage.

Darwent also addresses the issues of Inuit subsistence strategies from the 'high Artic,' described as '…marginal, inhospitable, and unforgiving…' This fearsome region was none the less extensively settled by Palaeoeskimo peoples, with a remarkable 68 faunal collections from the Canadian Arctic and from Greenland available to be examined. The virtual absence of the dog from these assemblages is always a surprise, as evidenced both by the lack of dog bones and from the scarcity of tooth marks on the bones of other mammals. The faunas show considerable fluctuation in composition. In the high Arctic the contribution from large land mammals (the caribou and musk ox) was comparatively slight but there was a more extensive use of the smaller land mammals, mainly fox and hare. Darwent suggests that the faunal variability is due in part to changes in mobility pattern, mainly with the appearance of large communal houses in the late Dorset culture; in the author's own words '…climate alone does not adequately explain the variability in the Late Dorset faunal assemblages.' Sea mammals too played an important role in the economy, frequently the bearded seal, and intermittently, the walrus. The later appearance of

this species is seen not in terms of environmental or ecological changes, but rather as the result of a technological shift, following the invention of the heavy harpoon. Inevitably a paper of this scope must leave many questions open. The reader will obviously need to examine the fuller accounts of Darwent's work for a wider understanding of her methodology, as questions such as the effectiveness of bone recovery in the earlier excavations of the author's sample and ways in which bones were counted for the statistical treatment cannot can be fully answered in a short conference paper.

Borrero too addresses the culturally conditioned meaning of 'marginality,' stressing the biogeographical meaning of the term rather than that of implying a low population density or a limited cultural repertoire. Popular European perceptions of Patagonia are indeed those of both geographical remoteness and of challenging conditions for early human settlement. It represents the final stopping place in that most remarkable of human adventures, the peopling of the Americas. Charles Darwin left us with vivid, if highly prejudiced, images of the people. While admiring the tall stature of the people that he met at 'Good Success Bay,' other of the Fuegian population were less impressive – '…abject and miserable creatures…' and '…stunted, miserable wretches…' (Darwin 1860). Like others, Darwin was unimpressed by the simple technology of the Fuegian population, seeing the lack of clothing and simple tools as indicative of a truly lowly human state, '…much capable of improvement.' Borrero shows that the early Patagonian populations had risen to a far greater challenge than Darwin could have imagined, being present from the very end of the Pleistocene period, close on the time of the extinction of the megafauna. At some sites there is evidence of humans and the remains of megafauna. Other sites, close to the Ice Cap, show intermittent occupations that were based on the exploitation of the guanaco and the huemul, the native deer *Hippocamelus bisulcus*, but apparently in occupations of restricted nature, with long periods of abandonment – marginal in any sense of the term.

Remaining for the moment in the Americas, Schmitt, Madsen and Lupo travel to the other extreme of 'marginality' – that of extreme heat and aridity in the Bonneville Basin. Here, the Holocene climatic record is one of progressive desertification, bringing about an abrupt change from sagebrush and grassland to xerophytic scrublands, marked by a rise in abundance of the desert adapted jackrabbit, *Lepus californicus.* The Camels Back Cave gives a stratified sequence of human occupations over the last 7500 years, apparently of brief and small-scale settlement episodes. The sequence from the Homestead Cave some 120 km to the north shows a moist early Holocene giving way to a more arid mid-Holocene, as does the small mammal fauna of Camels Back Cave. By 8000 years 95% of the leporid fauna was of *Lepus* rather than *Sylvilagus,* the cottontail. The authors carefully consider the origin of the faunal samples, comparing these with the patterns deposited by carnivorous mammals and birds; the human occupations are put into perspective as '…brief stays…by small groups of mobile foragers.' This is a truly marginal site in a difficult habitat, shown by the fauna that was exploited.

Bar-Oz and colleagues describe the fauna from a cave and a rockshelter in the southwestern Caucasus mountains, though the degree of 'marginality' is of a different sort to that seen in the previous studies. Two little known species were hunted – the steppe bison and Caucasian goat –, and smaller percentages of *Bos*, *Equus*, *Cervus*, *Sus* and *Capreolus* were found. Proper attention was given to the use of sieve recovery for the bones. Some of the larger mammal species made pronounced altitudinal shifts between the summer and winter seasons in the recent past. The detailed taphonomic analysis points up the difference between the heavily weathered bones of the upper Palaeolithic layers at Dzudzuana Cave and the fresh material that was deposited at the middle and upper Palaeolithic Ortvale Klde shelter. There is also evidence for the hunting of 'prime age adults' at both sites, though with the evidence for bone weathering at Dzudzuana cave, there will have been a bias against the preservation of the juvenile mandibles that will doubtless be considered in the full report on the site. The low frequency of carnivore gnawing on the bones is interpreted as signs of prolonged residence, though, bearing in mind the evidence for recent altitudinal migration for two major prey species, this will need to be more fully explored. Obviously this study represents the early stages of a comprehensive faunal study, and inevitably many questions remain to be fully answered. We shall await the final outcome with anticipation.

Arnold and Greenfield present a substantial contribution about the possible beginnings of transhumant pastoralism in southeastern Europe. In this context 'marginality' is seen as the situation arising from ever greater intensification of arable cultivation, thus displacing the herds to grazing lands where cultivation was impossible. This is a very different case study from the others given in this section. The paper provides a discussion of the meanings of the words 'transhumance' and 'pastoralism' – terms as problematic in their way as is 'marginality.' The paper also gives us a detailed discussion of the faunal evidence for seasonality in occupation, based upon the tooth eruption in the jaws of the familiar domestic species, courageously extending this analysis even to the pig. The problem is that this type of analysis requires bone samples that are both very well preserved and were very carefully recovered. The mandibles of caprines can give good patterns of seasonal killing, being fast developing and the species most likely to have had a marked seasonal birth (Legge, Williams and Williams 1991, 1998). An extensive survey of the data comes up with no evidence to support the development of a mobile element to otherwise sedentary agricultural communities in either the Neolithic or the Bronze Age of the region. However,

as the authors themselves say, there is a continuing need for investigations of this sort, preferably based first on ideal samples, both well preserved and very carefully recovered.

The papers in this section are varied in their content and in the way that each sees the concept of 'marginality.' Yet however the word is interpreted, the contributors do not see the concept as of limited interest or of little significance in human history. In popular meaning, we use words differently. We might describe an event as 'marginal' or possibly as 'peripheral' if it is of little immediate concern to us, or unimportant. Indeed, in the human past some peoples may have found themselves to be truly marginal in any sense of the word – isolated in blind alleys, marooned on small islands or in other places with little or no external contact. More constructively, it can be seen that more commonly to be 'marginal' is to be pushing at the limits of human experience. Thus most of the major innovations in human history were, at their inception, *marginal* adaptations, from the first bipedal foot outside of Africa to the very beginnings of agriculture – both hazardous, marginal adventures at the outset, but ones that created the modern world. What began at the edge has become the very centre.

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